# ESTIMATES OF METHANE EMISSIONS FROM THE U.S. OIL INDUSTRY

FINAL DRAFT

Prepared for:

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# TABLE OF CONTENTS

# METHANE EMISSIONS FROM THE U.S. OIL INDUSTRY

## EXECUTIVE SUMMARY

Methane emissions from anthropogenic sources contribute significantly to the concentration of greenhouse gases in the earth's atmosphere. Reduced emissions from anthropogenic sources, including those associated with the U.S. oil industry, could have a considerable positive environmental impact. Because of the similarities that exist between oil and natural gas production operations, methods currently being used to reduce emissions in natural gas production operations are often transferable to oil production operations.

Unlike many other atmospheric emissions, methane has value as an energy resource, which provides an economic incentive for reducing losses. Economic recovery of the methane is an important consideration in motivating companies to install the equipment needed to reduce emissions. Economic recovery of methane depends on:

- The volume of methane and other associated hydrocarbon gases available for recovery;
- The value of the methane and other associated hydrocarbon gases;
- The availability of a recovery technology; and
- The costs of gas recovery and transportation to a processing plant.

The purposes of this study are to: 1) develop an improved estimate of U.S. oil industry methane emissions; 2) identify the technical potential of options for reducing oil industry methane emissions; and 3) evaluate the economics of reducing methane emissions from the significant emission sources identified. The study background and methodology are laid out in Chapters I and II. Chapter III provides both the latest estimates of oil industry methane emissions and descriptions of how these estimates have been developed. In Chapter IV, areas for potential improvements in the emissions estimates are offered. Chapter V describes the options available to reduce oil industry methane emissions and evaluates their cost effectiveness. Chapter VI summarizes the conclusions reached from the study.

### Methane Emission Estimates

Oil-related methane emissions are primarily associated with crude oil production, transportation and refining. Annual methane emission estimates for these three sectors totaled 61 billion cubic feet (Bcf) in 1995. This number is substantially lower than the most comprehensive previous study, by Radian International in 1996, which estimated 1993 emissions at 98 Bcf.[1] There are two primary reasons for this difference: 1) the current study accounts for differences between the oil and gas industries when using gas industry data, and 2) the current study incorporated significant industry input through workshops and peer reviews.

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[1] Radian International LLC, *Methane Emissions From the U.S. Petroleum Industry*, draft report for the U.S. Environmental Protection Agency, June 14, 1996.

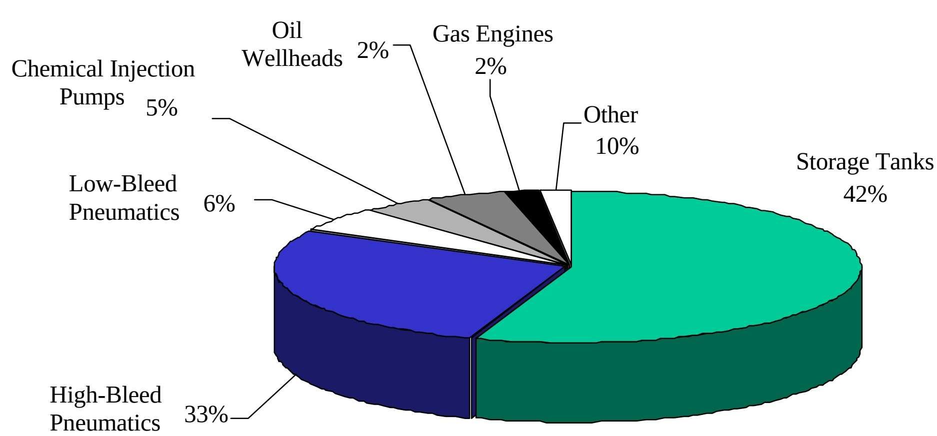
At an estimated 59.1 Bcf, the production sector of the oil industry has by far the largest emission rate of the three sectors. The crude oil transportation and refining sectors are estimated at 0.3 Bcf and 1.3 Bcf, respectively. Thus, the producing sector is responsible for 97 percent of the total methane emissions from the oil industry. The following table summarizes emission estimates for the three sectors. Tables C-1, C-2, and C-3 in Appendix C provide a detailed look at the emissions from each sector.

**Methane Emission Estimates by Sectors**

| Oil Industry Sector | Emission Estimate (Bcf/yr) | Percent of Total |
|---|---|---|
| Crude Oil Production | 59.1 | 97% |
| Crude Oil Transportation | 0.3 | <1% |
| Crude Oil Refining | 1.3 | 2% |
| Total | 60.7 | 100% |

Emissions from the various sectors of the oil industry are broken down into four types — fugitive emissions (unintentional leaks), vented emissions (intentional leaks), operational upset emissions, and emissions from the combustion of fuels (these are described in Chapter 3). Emissions in the production sector are further concentrated into six "significant sources," which represent over 90 percent of all methane emissions from the oil industry. These sources include vented emissions from oil tanks, high and low-bleed pneumatic devices, chemical injection pumps, and light crude oil wellheads, as well as combustion emissions from gas engines. The term "significant source" refers to those that are estimated to emit at least 1.0 Bcf of methane nationally per year. There are no significant methane emission sources in the crude transportation and refining sectors. Throughout the report, the term "source" refers to a category of items that emit methane, not individual items.

**Sources of Methane Emissions in the Oil Industry**



### Methane Emission Reduction Potential

The technical potential and economic feasibility of emission reductions are estimated for each emission source identified. For the six significant sources, the economics of emission reductions were evaluated more rigorously.

The technical potential for methane emission reductions from all sources is an estimated 44 Bcf. This represents an 73 percent reduction from the industry's total methane emissions. An estimated 14 Bcf of the methane released could be retained economically in oil industry production systems. The emission reduction options that have been evaluated and their estimated effectiveness for the significant sources are summarized in the following table.

**Methane Emission Reduction Estimates for Significant Sources**

| Significant Emission Source | Emission Reduction Option | Emission Rate (Bcf/yr) | Emission Reductions | |
|---|---|---|---|---|
| | | | Technical Potential (Bcf/yr) | Economically Feasible (Bcf/yr) |
| Storage tanks | Install vapor recovery or flare systems | 25.8 | 24.4 | 8.2 |
| Pneumatic devices (high-bleed) | Replace or modify pneumatic devices | 19.9 | 17.5 | 4.9 |
| Pneumatic devices (low-bleed) | Use directed I/M programs | 3.7 | 0.4 | 0.2 |
| Chemical injection pumps | Use air-drive, motor-drive, or high efficiency pumps | 2.8 | 0.7 | 0.0 |
| Oil wellheads (light crude) | Use directed I/M programs | 1.3 | 0.6 | 0.3 |
| Gas engines | Use electric motors* or low emission engines | 1.4 | 0.1 | 0.1 |
| Totals | | 54.8 | 43.7 | 13.7 |

*Electric motors reduce local emissions but overall emission reduction depends on the source of electricity.

### Principal Conclusions

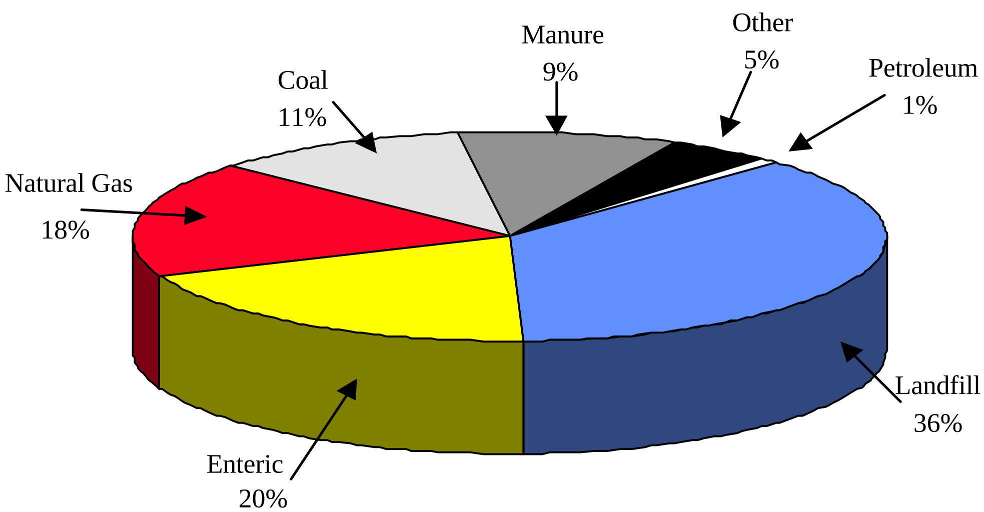
The principal conclusions of this study are as follows:

- The oil industry releases significant volumes of methane to the atmosphere;
- These volumes are concentrated in a small number of production sector sources; and
- Technologies are available to reduce a significant share of these emissions.

# I. BACKGROUND

According to EPA's *U.S. Greenhouse Gas Emissions and Sinks: 1990-1996*, "atmospheric methane is an integral component of the greenhouse effect, second only to carbon dioxide as a contributor to anthropogenic greenhouse gas emissions." Moreover, over a 100-year period, methane is estimated to be 21 times more effective than $CO_2$ at trapping heat in the atmosphere.[2] In addition to the oil industry, primary anthropogenic methane sources are landfills, domesticated livestock, coal mining, livestock manure, and natural gas systems. Other smaller sources include rice cultivation, industrial processes, and changes in land use.[3] The following chart shows the breakdown of the primary anthropogenic sources of methane emissions in the U.S. Data for the oil industry was updated to include the results of the current study.

**U.S. Sources of Methane Emissions in 1995**[4]




Controlling methane emissions is one of the most effective means of mitigating global climate change in the short term because the atmospheric life of methane is shorter than other major greenhouse gases. Methane is an excellent candidate for mitigating climate change impacts because emission reductions could lead to a stabilization or reduction in atmospheric methane concentrations within 10 to 20 years. It is estimated that a 10 percent reduction of total anthropogenic methane emissions worldwide would halt the annual rise in methane concentrations.

Since methane is the major component of natural gas, methane emissions during production, processing, transmission, and distribution of natural gas can be significant. According to EPA's greenhouse gas inventory, methane emissions from natural gas systems have remained relatively constant in

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[2] Environmental Protection Agency, *U.S. Greenhouse Gas Emissions and Sinks: 1990-1996*, 1998 (draft).

[3] Ibid.

[4] Ibid.

the 1990s. Natural gas facilities account for over 18 percent of methane emissions in the U.S. Although there are over a million miles of pipeline and thousands of facilities now in operation, most methane emissions stem from a small number of high-leak facilities. The EPA Natural Gas STAR program has demonstrated that targeting high-leak facilities or components can result in substantial emission reductions. Furthermore, since methane has value as an energy resource, these emission reductions can often be profitable for producers.

Emissions from oil production, transportation, and refining facilities involve technology similar to the natural gas production, transportation, and processing. Figure 1 shows the flow of oil and gas production from the wellhead to market, demonstrating the points of similarity between the two. As a result, some methods for reducing emissions in natural gas production and processing can be readily transferred to oil production. Economic recovery of the methane is an important consideration in motivating companies to install the necessary equipment to reduce emissions. Factors determining the cost-effectiveness of emission reductions include the volume of methane present in the oil, access to a gas gathering system, and the availability of an efficient technology to recover or reduce the emissions.

To date, most studies of methane emissions from the petroleum industry have focused on the natural gas sector. Other than Gas Research Institute (GRI) reports, these studies have often included oil industry estimates with gas industry estimates. EPA, the American Petroleum Institute (API), and the Canadian Association of Petroleum Producers (CAPP) have conducted several studies focusing on the oil industry, but these were generally broad estimates, such as industry total or sector total, rather than by equipment item.[5] The most recent and comprehensive previous work on methane emissions from the oil industry was performed for EPA by Radian International LLC.[6] The Radian study, however, did not evaluate emission reduction methods. Appendix A provides a list of the references used in preparation of this report.

Despite the similarities between the oil and natural gas industries, there are many differences that necessitate a detailed report of oil-specific methane emissions. In the oil industry, unlike the natural gas industry, methane is usually a small part of total emissions. An emission from an individual oil industry source may contain numerous ingredients, such as a mixture of gaseous and/or liquid hydrocarbons that may include methane, hydrogen, carbon dioxide, nitrogen, oxygen, and water vapor. Furthermore, most of the processes involved in the two industries differ to some extent, resulting in different activity and emission factors (see Methodology section for explanation).

This study aims to fill the gap in existing data by focusing strictly on oil industry methane emissions and taking into account differences between gas and oil industry data. The purposes of this study are to: 1) develop an improved estimate of U.S. oil industry methane emissions; 2) identify the technical potential of options for reducing oil industry methane emissions; and 3) evaluate the economics of reducing methane emissions from the significant emission sources identified.

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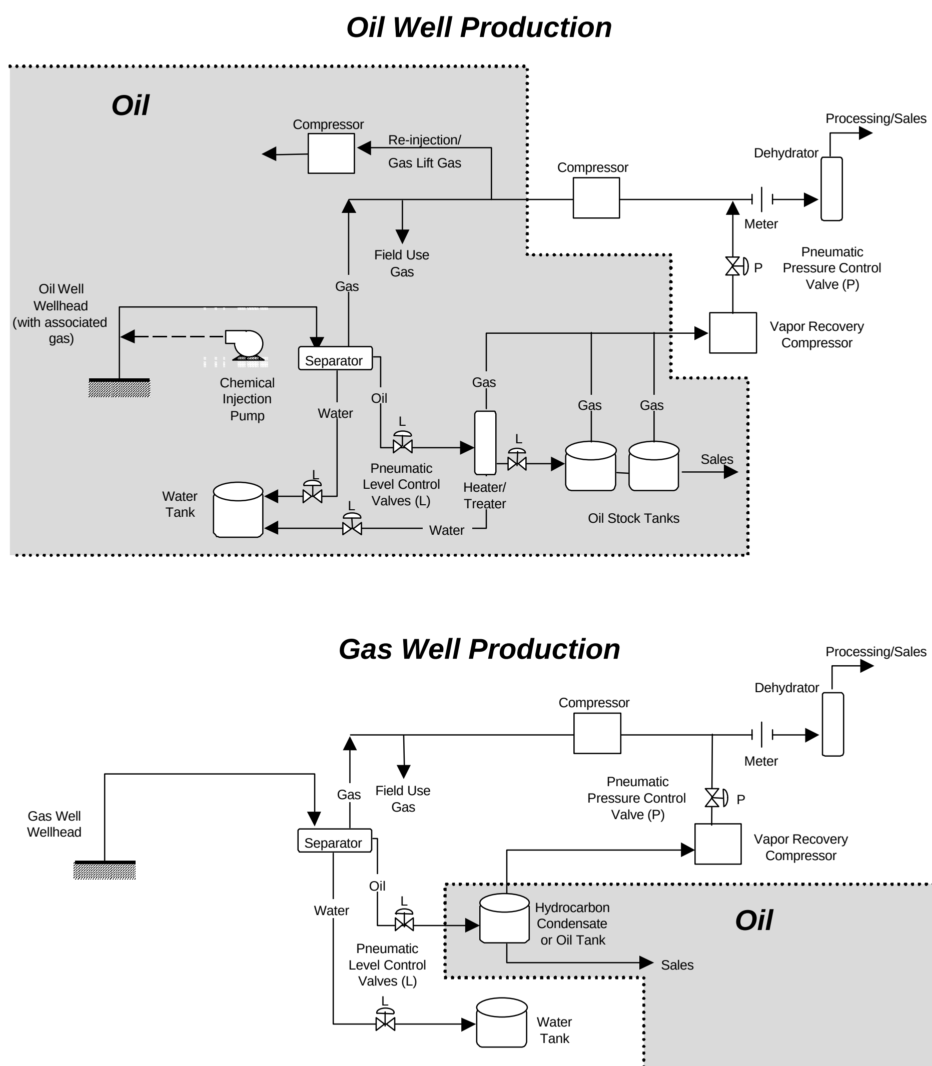
[5] Appendix D contains a comparison of previous studies of methane emissions in the oil industry.

[6] Radian International LLC, *Methane Emissions From the U.S. Petroleum Industry*, draft report for the U.S. Environmental Protection Agency, June 14, 1996. Because this report was the starting point for the current study, it is frequently cited. To reduce repetitiveness, it will generally be referred to in the text as the 'Radian report.'

# II. METHODOLOGY

The methodology used to estimate oil industry methane emissions involved developing emission factors and activity factors. Emission factors measure the average emissions per source (e.g., emission rate per equipment item or per activity). Activity factors are estimates of the number of equipment items or frequency of activity. Total emissions from a source are estimated by multiplying the emission factor by the activity factor. The activity and emission factors were developed using a variety of sources, including a literature survey, emission and activity factor updating, and reviews by oil industry experts. A number of sources were also used to determine available technologies for reducing emissions. Recent studies, including EPA's *Lessons Learned* for the Natural Gas STAR program and a CAPP report on methane reduction, were evaluated to develop initial lists of reduction options. These were further refined through input from industry reviewers. This combination of identifying and using the best and/or

**Figure 1. Oil & Gas Industry Boundaries**



most up-to-date published information available and enhancing it with current industry expertise provides an improved estimate of methane emissions for the oil industry. Appendix B identifies the oil industry representatives that reviewed this report.

## III. Emission Estimates

Methane emission estimates from the oil industry are described in the following paragraphs and detailed by industry sector in Tables C-1 (Production), C-2 (Transportation), and C-3 (Refining) of Appendix C. The emission sources for each oil industry sector are aggregated into four types of emissions — vented, fugitive, combustion, and operational upset emissions.

- Vented emissions are intentional releases to the atmosphere by facility design or operational practice. Examples of vented emissions are the continuous releases from vented storage tanks; occasional depressurizing of process equipment and piping prior to maintenance procedures; and cycling releases from equipment that is driven by pressurized gas, such as pneumatic control devices and chemical injection pumps.

- Fugitive emissions are unintentional, and typically continuous, releases associated with leaks caused by failure of the integrity of a component within a system. Common leak sources are valve stem packing, pipe flange gaskets, smaller pipe connectors, and seals on pumps, compressors, and floating roof tanks.

- Combustion emissions are the product of the burning of fuels. Examples of combustion emissions are the exhausts of engines that drive reciprocating and centrifugal compressors, and the effluent from stacks on fired heaters and from waste gas flares.

- Upset emissions are unintentional releases that occur when a process goes out of control. Examples of process upset emissions are releases from emergency pressure relief valves, oil well blowouts during oil well drilling operations, and emergency offshore oil production platform shutdowns. Process upset emissions of methane are estimated for the production sector of the oil industry only because downstream of the production area methane is only a small part of the total emission from an oil process upset.

The annual methane emission estimates for the three oil industry sectors analyzed are estimated to total 61 billion cubic feet (Bcf) using 1995 data for activity factors, as shown in Table III-1. This estimate is approximately 38 percent lower than the most comprehensive previous estimate of 98 Bcf, developed by Radian using 1993 data. Prior to the Radian report, most studies on oil industry methane emissions were on a broad, industry-wide scale, rather than focusing on individual equipment items. These earlier studies estimated much lower total oil industry methane emissions than the current study, ranging from 5 to 31 Bcf per year.[7] Comparisons of the current methane emission estimates with those made by Radian and others are tabulated in Appendix D.

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[7] API's 1992 *Global Emissions of Methane from Petroleum Sources* estimated U.S. emissions at 5.9 Bcf. EPA's 1990 Report to Congress estimated between 5.2 and 31.2 Bcf.

**Table III-1**
**Methane Emission Estimates by Sectors**

| Oil Industry Sector | Emission Estimate (Bcf/yr) | Percent of Total |
|---|---|---|
| Crude Oil Production | 59.1 | 97% |
| Crude Oil Transportation | 0.3 | <1% |
| Crude Oil Refining | 1.3 | 2% |
| Total | 60.7 | 100% |

## A. Production Sector Emissions

The production sector is estimated to have the largest methane emissions, from both individual sources and as an overall sector. Total production sector emissions are estimated to have been 59.1 Bcf/yr in 1995. The largest individual sources are estimated to be venting of crude oil storage tanks (25.7 Bcf/yr), venting from high-bleed pneumatic devices (19.9 Bcf/yr), venting from low-bleed pneumatic devices (3.7 Bcf/yr), and venting from chemical injection pumps (2.8 Bcf/yr).

Venting emissions total 53.7 Bcf/yr and comprise 91 percent of the total emissions from this sector. Fugitive emissions, which total 3.0 Bcf/yr, account for 5 percent. Combustion emissions, totaling 1.8 Bcf/yr, make up 3 percent of the 1995 total. Emissions from process upsets account for approximately one percent of total emissions, with only 0.6 Bcf/yr. Table III-2, below, summarizes the production sector emissions by type. Table C-1 in Appendix C provides details of methane emission estimates for all 39 identified emission sources in the production sector.

**Table III-2**

**1995 Production Sector Emission Estimates by Type of Emission**

| Type of Emission | Emission Estimate (Bcf/yr) | Percent of Total |
|---|---|---|
| Vented | 53.7 | 91% |
| Fugitive | 3.0 | 5% |
| Combustion | 1.8 | 3% |
| Upsets | 0.6 | <1% |
| Total | 59.1 | 100% |

The following paragraphs describe the sources of production sector methane emissions. They also discuss how the emission factors and activity factors were determined for each of the significant production sector emission sources. Because 90 percent of methane emissions from the oil production sector come from just six sources that each emit over 1.0 Bcf/yr, this study focuses on these significant sources.

## 1. Production Vented Emissions

In the oil production sector, methane emissions are vented from 13 sources and are estimated at 54 Bcf for 1995. The four significant sources — storage tanks, high and low-bleed pneumatic control devices, and chemical injection pumps — emit an estimated 52 Bcf/yr, or 97 percent of the total. Losses from the other 9 identified sources range from zero to 0.8 Bcf/yr. Table III-3 summarizes the vented emission rates from the production sector.

**Table III-3**
**Summary of Vented Emissions From the Production Sector**

| Emission Source | Emission Estimate (Bcf/yr) | Percent of Total |
|---|---|---|
| **Significant Sources** | | |
| Storage Tanks | 25.7 | 48% |
| High-Bleed Pneumatic Devices | 19.9 | 37% |
| Low-Bleed Pneumatic Devices | 3.7 | 7% |
| Chemical Injection Pumps | 2.8 | 5% |
| **Smaller Sources Total** | 1.7 | 3% |
| Totals | 53.8 | 100% |

<u>Storage Tank Vented Emissions</u>

Venting from oil storage tanks is the largest source of methane emissions in the oil industry, with an estimated 26 Bcf emitted per year. These tanks hold crude oil that has been through a separator, (a pressure vessel used to separate well fluids into oil, gas, and water). When the crude enters the storage tanks, which are at atmospheric pressure, some of the dissolved gases and lighter liquid hydrocarbons flash off (vaporize). Most of these tanks are vented to the atmosphere, allowing methane and other gases to escape.

The emission factor for tank venting was developed using API's *E&P TANK* program and assuming that essentially all tanks in crude production service are the fixed roof design.[8] *E&P TANK* is designed to calculate the emissions of 22 components (including methane) from individual oil production sites using measured characteristics of the site and of the crude oil properties. Important crude oil parameters include pressure, temperature, gravity, and vapor pressure. To develop the emission factor used in this study, the sample cases[9] included in *E&P TANK* were run and a weighted average of the results was obtained. Using these samples to estimate total U.S. methane emissions requires assuming that the sample sites are a fair representation of total U.S. oil production. This assumption has not been tested, but

[8] Most tanks in the oil production sector have fixed roofs and emit gas primarily through venting. Floating roof tanks, which produce fugitive emissions, are prevalent in other sectors of the oil industry

[9] One of the samples was excluded from this study because it represented 67 percent of the total production rate included in the 103 sites, skewing the results significantly.

is believed to be a reasonable approach to estimating U.S. methane emissions from production site tanks for the current analysis. The *E&P TANK* computations provide an emission factor of 18 scf of methane per barrel of crude produced.

The activity factor for tank venting takes into account emission reductions from the use of vapor recovery systems, flaring and floating roof tanks. According to an unpublished API survey, nine percent of oil tanks are reported to have VRUs in place and two percent have flare systems.[10] When weighted for oil production rates by the states that are included in the API survey, the emission reductions caused by these systems affect 29 percent of U.S. oil production. In addition, methane vented from oil stripper wells does not enter the storage tanks. These two deductions reduce total crude oil production from 2,394 million barrels in 1995 to 1,434 million barrels. This provides an activity factor of 1.4 billion barrels for 1995. When multiplied by the 18 scf/barrel emission factor, tank batteries contribute 26 Bcf of methane emissions.

High-Bleed Pneumatic Device Vented Emissions

The pressurized gas that is released from the crude in the separator is often used in a facility's process control systems. The gas is used to transmit signals between sensing and control devices and to drive automatic control valves for controlling liquid levels, flow rates, and pressures. Pneumatic control valves are designed to bleed gas to the atmosphere as they cycle up and down to modulate the system being controlled.

Venting from high-bleed pneumatic devices[11] is the second largest source of methane emissions from the oil industry. In 1995, these devices released an estimated 19.9 Bcf, or 37 percent of total production vented releases. The emission factor used to derive this number is the EPA Natural Gas STAR program default value of 126 Mcf/year, which corresponds to 345 cubic feet per day (scfd).[12] The activity factor, 157,581 high-bleed devices, assumes that tank batteries with heater treaters have four pneumatic devices (three level controllers and one pressure controller). Tank batteries without heater treaters are assumed to have three devices. The share of high-bleed devices is estimated using an EPA/GRI study[13] showing that 35 percent of more than 4,000 devices observed were high-bleed types.

Low-Bleed Pneumatic Device Vented Emissions

Venting from low-bleed rate pneumatic controllers is estimated to add another 3.7 Bcf of methane emissions to the high-bleed venting of 19.9 Bcf. The emission factor for low-bleed devices is estimated by EPA to be only 10 percent of the activity factor for high-bleed devices, or 35 scfd per device.[14] The activity factor for low-bleed devices is 292,650 devices; this is 65 percent of the total number of production sector devices estimated, based on the EPA survey described in the previous paragraph.

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[10] API, Unpublished data from survey of major and independent producers, 1996.

[11] Pneumatic devices are defined as "high-bleed" if they vent more than 6 scf per hour (scfh).

[12] EPA/GRI, *Methane Emissions from the Natural Gas Industry, Volume 12: Pneumatic Devices*, prepared by Radian, June 1996.

[13] Ibid.

[14] EPA Natural Gas STAR Program default value for low-bleed pneumatic devices is ten percent of the high-bleed rate of 126 Mcf/year.

Chemical Injection Pump Vented Emissions

Chemical injection pumps are used to inject various chemicals into crude oil at the well site. The injected chemicals are used to break oil-water emulsions, inhibit corrosion, dewax paraffins, kill bacteria, and control other processing problems. As in the case of pneumatic devices, the pressurized natural gas that is frequently available at oil production sites may be used to drive chemical injection pumps. Chemical injection pumps account for an estimated 2.8 Bcf/yr of production sector vented emissions. The EPA/GRI estimated average emission rate for each pump is 91 Mcf/yr.[15] The activity factor is computed by using the Radian estimate of 125,088 pumps and a pump manufacturer's estimate that only 25 percent of these pumps are driven by gas.[16] The remainder are driven mechanically or by electric motors or compressed air.[17]

Offshore Production Platform Vented Emissions

In 1993, the Minerals Management Service (MMS) estimated oil and gas production platform total hydrocarbon emissions in the Gulf of Mexico Outer Continental Shelf (OCS).[18] The MMS study encompasses all of the sources located on the platforms, such as engines, pumps, and pneumatic devices. Specific emissions sources are not detailed in the MMS report, except for crude oil and diesel oil tanks which comprise only five percent of the total. Based on methane venting rates from onshore production sites, the remaining 95 percent of vented emissions are likely to be primarily from pneumatic devices and chemical injection pumps.

Using the MMS study, oil platform methane emissions in the Gulf are estimated to be approximately 0.8 Bcf per year. This rate is calculated by assuming that: 1) 61 percent of the vented hydrocarbons from oil and gas platforms are methane,[19] and 2) 14 percent of the emissions are from oil platforms. The 14 percent assumption is based on EIA production data showing that 14 percent of natural gas production in the Gulf in 1995 was associated-dissolved gas, which is produced in association with oil.[20] The remaining 86 percent was produced from gas wells, which are located on platforms primarily producing gas and are outside the scope of this study.

The MMS estimate of total hydrocarbon emissions from offshore platforms in the Federal waters in the Gulf of Mexico was based on a count of 1,807 platforms. It should be noted that this MMS approach does not include the emissions from the smaller platforms located in state waters in the Gulf of Mexico, which represent around 5 percent of total offshore Gulf production.[21] To account for state offshore

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[15] EPA/GRI, *Methane Emissions from the Natural Gas Industry, Volume 8: Equipment Leaks*, prepared by Radian, June 1996.

[16] Ron Rayman, Dresser Texsteam, Personal Communication. Dresser Industries is one of the largest suppliers of chemical injection pumps in the industry. Mr. Rayman estimated that approximately 25 percent of Dresser's chemical injection pumps run on methane. Representatives from Moyno Oilfield Products and Danco Pump & Supply Co. both agreed that most chemical injection pumps are operated with electric motors.

[17] Please see discussion in Chapter IV, *Potential Improvements*.

[18] Minerals Management Service, *Gulf of Mexico Air Quality Study*, August 1995.

[19] Light crude speciation fraction for total hydrocarbon emissions from API's Workbook No. 4638.

[20] U.S. Department of Energy, Energy Information Administration, *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, Annual Report 1995.*

[21] DOE, EIA, *Petroleum Supply Annual 1995*.

production, 5 percent has been added to the MMS estimate. See Table E-1 in Appendix E for a summary of the MMS hydrocarbon emission estimates.

Emissions from offshore areas other than the Gulf are estimated using the Gulf emission factor and the 22 platforms identified by Radian. The resulting vented emission rate is 0.01 Bcf.

Stripper Well Vented Emissions

Stripper wells are those that produce fewer than ten barrels of oil a day. The average production rate for U.S. stripper wells is 2.1 barrels per day;[22] approximately one-third of the 434,000 stripper wells in the U.S. produce an average of one barrel of crude per day. Methane is emitted from the casinghead valves[23] on an estimated 80 percent of stripper wells that are left open to maximize oil flow. This is because gas pressure buildup in the well casing can restrict the already slow drainage of oil from the reservoir into the well. Based on an estimated gas/oil ratio of five scf of gas per barrel of crude,[24] the annual total hydrocarbon gas emission is 3,832 scf per stripper well. Using the API Publication No. 4638 speciation fraction of 0.612 for light oil methane content, the annual methane emission factor is 2,345 scf per stripper well. For the 347,500 stripper wells that are vented, the annual methane emission rate is estimated to be 0.82 Bcf.

Other Vented Emissions

There are several smaller sources of vented emissions in the production sector: pressure vessel and compressor blowdowns, compressor starting, and oil well completions and workovers. Emission factors for these sources are taken from Radian. The activity factors for pressure vessels (combination of separators and heater treaters) and small compressors are taken from the fugitive emissions section of this report. The activity factor for oil well completions comes from DOE’s Energy Information Administration.[25] The number of oil well workovers is estimated by Radian to be 7.5 percent of producing wells each year. Table C-1 in Appendix C provides the details of emission and activity factors for each of these venting sources.

## 2. Production Fugitive Emissions

Total fugitive emissions from 16 oil production sources are estimated at 2.9 Bcf for 1995. Wellheads producing light crude oil are the only significant source of fugitives, emitting an estimated 1.3 Bcf, or 45 percent of the total. Losses from the other 15 identified sources range from near zero to 0.6 Bcf each. Table III-4 summarizes the fugitive emission sources from the production sector.

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[22] API, *Basic Petroleum Databook*, July 1997.

[23] The pipes that are used in oil wells to seal off fluids from the bore hole are called casing. The casinghead is the part of the casing that protrudes above the surface and holds the control valves and flow pipes.

[24] ARCO Laboratory, Plano, TX, personal communication. Based on assumed reservoir pressures of 25 to 50 psia.

[25] U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review*, April 1997.

**Table III-4**
**Summary of Fugitive Emissions From the Production Sector**

| Emission Source | Emission Estimate (Bcf/yr) | Percent of Total |
|---|---|---|
| **Significant sources** | | |
| Light oil wellheads | 1.3 | 43% |
| **Smaller sources total** | 1.7 | 57% |
| Totals | 3.0 | 100% |

Oil Wellhead Fugitive Emissions

Oil wellheads are the above-ground extension of oil wells where production control and measurement facilities are located. Wellheads are formed by a combination of parts; in this study, potential leak sources of a typical oil wellhead are assumed to be five valves, ten flanges, four small pipe connections, and a polished rod stuffing box.[26] For light crude wellheads (API gravity above 20°), the emission factor is estimated to be 16.6 scf per well per day. This was calculated using the average total hydrocarbon (THC) leak rates for each component from the API No. 4638 Workbook and the workbook's estimate that methane accounts for 61.2 percent of THC emissions.[27] The activity factor of 210,946 light crude producing wells was estimated using API data[28] for the number of producing oil wells less stripper wells, and the Radian estimate that 93 percent of oil wells produce light crude. Total emissions from light crude oil wellheads are estimated to be 1.3 Bcf.

Emissions from the seven percent of non-stripper wellheads that produce heavy crude were calculated to be 0.001 Bcf using the component leak rates and THC speciation fraction of 0.94 for methane from heavy crude reported in the API workbook.[29]

Offshore Platform Fugitive Emissions

Fugitive emissions from offshore platforms in the Gulf of Mexico are estimated to be 0.04 Bcf. This estimate is based on the same sources and assumptions described earlier under offshore platform vented emissions. It is important to note that these emissions represent those associated with production operations only. During some offshore drilling operations, some gas produced in association with oil may be flared (or in rare cases vented). When this does occur, it is only for a very short time and the total emissions associated with this activity would be quite small. As with vented emission estimates, the fugitive emission estimates for the Gulf of Mexico only consider emissions from production operations in

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[26] Consensus of industry review panel.

[27] American Petroleum Institute, *Calculation Workbook for Oil and Gas Production Equipment Fugitive Emissions, No. 4638,* by Star Environmental, July 1996.

[28] American Petroleum Institute, *Basic Petroleum Data Book*, January 1997.

[29] API Workbook No. 4638.

Federal waters. However, since 95 percent of all Gulf of Mexico offshore associated-dissolved gas production takes place in Federal waters, this should have an insignificant impact on total emissions.

Fugitive methane emissions from offshore locations other than the Gulf are estimated using the fugitive emission factor from the Gulf and the 22 platforms in the Pacific and Alaskan offshore, as described in the section on vented emissions. The estimate of fugitive emissions for offshore oil platforms not in the Gulf is 0.001 Bcf.

Separator, Heater Treater, and Header Fugitive Emissions

Additional sources of fugitive emissions in the production sector are: separators, which separate oil, gas and water; heater treaters, which separate crude oil and water; and headers, which are collection points for oil or gas gathering lines. Fugitive emissions from these sources are based on component leak rates from the API 4638 Workbook and average component numbers for each of the three sources. Emissions from these sources varied from near zero to 0.59 Bcf per source. Table C-1 in Appendix C provides details of the emission and activity factors for all of the fugitive emission sources.

Floating Roof Storage Tank Fugitive Emissions

Floating roof storage tanks have flat roofs that float on the surface of the oil, reducing evaporation to a minimum. Fugitive emissions from production sector floating roof storage tanks are small primarily because smaller, less expensive fixed roof tanks (which are vented) are used almost exclusively in this service. Even on Alaska's North Slope, where production rates are very high, fixed roof tanks with vapor recovery systems are used. Floating roof tanks for crude storage typically average 200 to 250 feet in diameter and there are fewer than 500 production sector tanks in this size range. Although no floating roof tanks have been identified in the production sector, an assumption is made that five percent of the larger tanks have floating roofs. As a result, the activity factor for floating roof production sector tanks is estimated to be 24 tanks.

The emission factor for crude storage in the production sector was estimated to be 0.3 MMcf (million cubic feet) per tank per year, using the API *TANKS* computer program which is documented in EPA's AP-42. The *TANKS* program is designed to estimate emissions of organic chemicals from storage tanks. Unlike API's *E&P TANK* program, *TANKS* allows the user to specify floating roof tanks for emission estimates. Thus, although *TANKS* is primarily designed for downstream operations, it was used here to estimate emissions from crude storage floating roof tanks at production facilities. Because the *TANKS* model is designed to estimate emissions from individual floating roof tanks, assumptions were made to characterize an average or typical tank. Appendix G lists the assumptions made for characterizing a typical floating roof tank and estimating emissions from these tanks. Emissions from floating roof tanks in the production sector are estimated to be 0.008 Bcf per year.

Compressor Fugitive Emissions

The emissions factor for compressors used at oil production sites (which are smaller than natural gas pipeline compressors) was estimated by oil industry experts to be 100 scfd per compressor. The activity factor of 2,797 compressors was taken from Radian; the resulting emissions estimate is 0.1 Bcf per year. No large compressors similar to those used in the gas transmission industry have been identified in the oil production sector.

Crude Sales Facility Fugitive Emissions

Fugitive emissions from crude sales facilities primarily stem from losses when trucks are filled. The fugitive emission estimate for crude sales facilities is based on the number of truck loadings per year and an emissions factor of 40.55 scf per loading. Approximately 25 percent of total sales volumes are transported by truck. The remaining 75 percent of sales are delivered by pipeline, with negligible emissions. Truck loadings are estimated at 1,995,000 per year, using 25 percent of total volumes and assuming an average of 300 barrels per truck. This results in an estimated annual emission rate of 0.08 Bcf.

Crude Production Area Pipeline Fugitive Emissions

Methane leakage rates from crude pipelines are estimated to be essentially zero, since crude is nearly totally degassed in storage tanks and any crude leaks from production area piping are quickly repaired.

Drilling Fugitive Emissions

No data for methane losses during oil well drilling operations have been identified. No emissions will occur until a hydrocarbon bearing formation is entered, at which point most emissions will be vented rather than fugitive.

Pump Fugitive Emissions

Pumps are used in the oil production sector to move crude oil through pipes. Methane can leak through the pump's various components, such as seals, connectors, and flanges. The 0.24 scfd per pump emission factor for leakage from battery pumps was calculated using component THC leak rates and methane contents of THC from API Publication No. 4615.[30] The activity factor is estimated to be 172,345 battery pumps, based on 2.5 wells per battery, one pump per battery equipped with a lease automatic custody transfer (LACT) unit, and assuming 75 percent of leases have a LACT unit.[31] The resulting annual emission rate is 0.015 Bcf.

## 3. Production Combustion Emissions

Total estimated emissions from combustion sources are 1.8 Bcf per year, with 80 percent coming from incomplete combustion of methane in gas engines. The remaining four sources (heaters, drilling rigs, flares, and offshore platforms) contribute from 0.001 to 0.3 Bcf per year. Table III-5 provides a summary of combustion emission sources from the production sector.

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[30] American Petroleum Institute, *Emission Factors for Oil and Gas Production Operations, No. 4615*, January 1995.

[31] Consensus of Industry Review Panel. A LACT unit is a system of oil handling on a lease that receives crude into tankage, measures and tests it, and puts it into a pipeline.

**Table III-5**
**Summary of Combustion Emissions From the Production Sector**

| Emission Source | Emission Estimate (Bcf/yr) | Percent of Total |
|---|---|---|
| **Significant sources** | | |
| Gas engines | 1.4 | 80% |
| **Smaller sources total** | 0.4 | 20% |
| Totals | 1.8 | 100% |

Engine Combustion Emissions

Gas-fueled engines include both internal combustion engines and gas combustion turbines used to drive compressors, pumps, and generators. In any gas-powered engine, some of the gas will not burn completely and methane will be emitted to the atmosphere. The methane emission factor for gas-fueled engines at oil production sites is estimated to be 0.08 scf per HP-hr. This factor is one-third of the value used by Radian, and is based on an estimation that these engines are 98 percent efficient.[32] The activity factor of 17,634 MMHP-hrs per year is taken from the Radian draft report. Gas engine combustion is estimated to have produced 1.4 Bcf of methane emissions in 1995.

Offshore Platform Combustion Emissions

At a total of 0.3 Bcf, offshore platforms are the second largest source of combustion emissions in the production sector. As described earlier in the section on venting, the platform emission estimates come from a MMS Gulf of Mexico OCS study.[33] Table E-1 in Appendix E provides details of the emission estimates made by the MMS.

Flare Combustion Emissions

For safety reasons, flares are used in oil production to burn vented gases that contain $H_2S$ or other highly combustible gases. Emissions from flares are based on estimates that 2.2 percent of tank emissions are flared and two percent of flared gases from production sites are unburned.[34] Studies by EPA and the Canadian Association of Petroleum Producers (CAPP) also estimate that methane is 98 percent destroyed in flares.[35, 36] This corresponds to an emission factor of 20 scf per Mcf flared. Using the 26 Bcf estimated above for oil tank vented emissions, the activity factor is calculated to be 0.56 Bcf. Total methane

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[32] Consensus of industry review panel.

[33] MMS, 1995

[34] Consensus of industry review panel.

[35] EPA/GRI, *Methane Emissions from the Natural Gas Industry, Volume 6: Vented and Combustion Source Summary*, prepared by Radian, June 1996.

[36] Canadian Association of Petroleum Producers, *A Detailed Inventory of $CH_4$ and VOC Emissions From Upstream Oil and Gas Operations in Alberta, Volume II*, March 1992.

emissions are estimated to be 0.01 Bcf. In rare cases where flared gas is not ignited by the pilot flame or electronic igniter, the flare will vent temporarily.

Well Drilling Combustion Emissions

Well drilling combustion emissions come from the engine/generator set used to power the drilling rig draw works, which serve as the power-control center for the hoisting gear and rotary elements of the drill column. The emission factor of 2,453 scf per well comes from a 1992 API report.[37] The activity factor for the 10,049 oil wells drilled in 1995 comes from API data and includes oil well completions and a proportionate share of dry holes.[38] The total emission estimate for combustion sources associated with drilling operations is 0.025 Bcf.

## 4. Production Upset Emissions

Process upset venting is the least significant source of methane emissions in the oil production sector. Upsets include offshore platform emergency shutdowns, pressure relief valve (PRV) releases, and well blowouts. With total emissions from upsets at only 0.6 Bcf per year, no individual source is significant. Table C-1 in Appendix C provides details of emission estimates from the four sources identified.

Offshore Platform Emergency Shutdown Emissions

The largest production upset emission estimate is 0.47 Bcf from offshore platform emergency shutdowns, which are a vital safety procedure. The isolation, size of crews in residence, and confined spaces of offshore platforms have placed high priorities on safe, tightly controlled operations. When processes vary from the tight control ranges, operations are shutdown quickly, causing gas venting. The 256,888 scf/yr per platform emission factor for emergency shutdowns is taken from 1996 GRI/EPA report.[39] The activity factor of 1,829 platforms is the sum of offshore platforms in the Gulf of Mexico (1,807) and other waters (22), as described in the vented emissions section.

Pressure Relief Valve Emissions

Pressure relief valves (PRVs) are usually installed on pressurized vessels to prevent catastrophic failure of the vessel from an uncontrolled pressure rise. In production facilities, the usual pressure vessels are separators and heater treaters. The emission factor of 34 scf/yr per PRV comes from the 1996 GRI/EPA report.[40] The activity factor of 200,000 is estimated by combining the number of field separators with the number of heater treaters (from the fugitive emissions section of this report). Total PRV emissions are estimated to be 0.007 Bcf.

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[37] API, *Global Emissions of Methane from Petroleum Sources*, prepared by Radian Corporation, February 1992.

[38] API, *Basic Petroleum Data Book*, 1995.

[39] EPA/GRI, *Methane Emissions from the Natural Gas Industry, Volume 7: Blow and Purge Activities*, prepared by Radian, June 1996.

[40] Ibid.

### Oil Well Blowout Emissions

Oil well blowouts occur when a drill bit enters a reservoir that is pressurized above the pressure level expected for the well depth. Normally anticipated pressures are approximately equal to the hydrostatic head of a column of salt water to the depth of the well. Higher pressures can be caused by water drives that have sources at higher altitudes than the well head or by geopressuring from soil overburden buildup on unconsolidated reservoir sands as can occur beneath river deltas. The estimated emission factors for offshore and onshore blowouts are 5.0 MMscf (million cubic feet) and 2.5 MMscf per blowout, respectively.[41] These emission factors, that are about ten times those used by Radian, are very uncertain even though industry judgement was involved in their estimation. The offshore blowout activity factor of 2.25 per year is from an MMS report showing nine OCS blowouts from 1991 to 1994.[42] The onshore blowout estimate is 33.5 per year, or less than 0.3 percent of wells drilled.[43] Total emissions from oil well blowouts are estimated to be 0.01 Bcf for offshore and 0.08 for onshore.

## B. Crude Transportation Sector Emissions

Of the three oil industry sectors analyzed, the crude transportation sector has the lowest methane emissions with a total of 0.3 Bcf per year. The two largest sources are venting from fixed roof tanks and during marine loading operations, each at 0.1 Bcf per year. Table III-6 provides a summary of crude transportation emission estimates by each type of emission.

**Table III-6**
**1995 Crude Transportation Sector Emission Estimates by Type of Emission**

| Type of Emission | Emission Estimate (Bcf/yr) | Percent of Total |
|---|---|---|
| Vented | 0.26 | 84% |
| Fugitive | 0.05 | 16% |
| Combustion | 0.00 | 0% |
| Total | 0.31 | 100% |

### 1. Crude Transportation Vented Emissions

Crude transportation vented emissions are estimated to be 0.26 Bcf per year. At 0.14 Bcf, methane vented during the loading of crude into marine vessels, tank trucks, and rail tank cars account for over half of these emissions. Venting from storage tanks, pumping station maintenance, and pipeline pigging

[41] Consensus of industry review panel.

[42] MMS, *Accidents Associated with Oil and Gas Operations – Outer Continental Shelf: 1991-1994* (MMS 95-0052).

[43] Consensus of industry review panel.

operations contribute the other half of emissions in this group. Table C-2 of Appendix C provides details of the methane emissions from crude transportation venting.

Marine Loading Vented Emissions

As crude oil is loaded into marine vessels, vapors are displaced by the oil and released to the atmosphere. The emission factor for marine loading of crude is estimated to be 2.54 scf per 1,000 gallons of crude loaded. The basis for this estimate are the AP-42[44] total hydrocarbon emission factors for barges and tankers loading crude and an estimate that 15 percent of the hydrocarbon emissions are methane.[45] An estimated 38,667 million gallons of crude oil is loaded in the U.S. each year, including exports and domestic movements by tankers and barges.[46] These factors provide an annual methane emission rate of 0.098 Bcf.

Truck and Rail Loading Vented Emissions

Similar to vented emissions from marine loading, methane is released during truck and rail loading as gas vapors are displaced by crude oil. The emission factor for truck and rail loading operations is taken from EPA AP-42,[47] assuming a mixture of splash and submerged loading[48] that results in 3.5 pounds of total hydrocarbons released per 1,000 gallons of crude transported. Using the Radian value of 15 percent methane in the total hydrocarbon emissions, the emission factor converts to 0.5 scf of methane per barrel of crude loaded per year. Activity factors for the number of barrels loaded in trucks and rail cars are taken from the Petroleum Supply Annual.[49] Combined emissions from truck and rail loading total 0.04 Bcf per year.

Storage Tank Vented Emissions

Storage tank vented emissions, which come from tank farms associated with crude terminals and pipelines, are estimated to be 0.11 Bcf per year. These emissions are substantially lower than those from vented tanks in the production sector for two reasons. First, the methane content of crude by the time it leaves the production area is only about 0.2 percent of the amount in crude as it enters production tankage. Second, most of the crude tankage capacity in the transportation sector is the floating roof type that releases fugitive (rather than vented) emissions, as described earlier. The emission factor of 20.6 scf per 1,000 barrels of crude is taken from a 1992 API report.[50] Crude oil delivered to refineries is used as the activity factor for transportation storage tanks because the oil stored in these tanks is generally on its way to a refinery. According to DOE's *Monthly Energy Review*, 5.1 billion barrels of crude were delivered to refineries in 1995.

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[44] EPA, *Compilation of Air Pollution Emission Factors*, AP-42, January 1995.

[45] API, *Global Emissions of Methane from Petroleum Sources, No. DR 140,* prepared by Radian, February 1992.

[46] United States Army Corps of Engineers, *Waterborne Commerce of the United States, 1995, Part 5: National Summaries*.

[47] EPA, AP-42, 1995.

[48] These procedures are described in the emission reduction section.

[49] DOE/EIA, *Petroleum Supply Annual 1996, Volume 1.*

[50] API, *No. DR 140,* prepared by Radian, February 1992.

Pumping Station Vented Emissions

Very small amounts of methane are emitted from crude that is exposed to the atmosphere when pipeline pumping stations are dismantled for maintenance. Pipeline Systems, Inc. (PSI) estimates that only 36.8 scf is released per station each year, based on component counts and emission rates.[51] The number of pumping stations in 1995 is reported by the Oil & Gas Journal to be 587.[52] Annual methane emissions from this source are essentially zero.

Pipeline Pigging Vented Emissions

Pigs, or scrapers, are cylindrical devices, equipped with blades and brushes, that are used to clean build-ups of water, rust, wax, sludge, or other materials from pipelines. Pipeline pigging operations are a potential source of methane emissions when pig stations are opened to inject and recover pigs. CAPP[53] estimates that the emission factor for pig stations is 39 scf per day per station. Assuming two pig stations per pumping station (one receiving and one injecting), the resulting activity factor of 1,174 stations provides an estimated annual emission rate of 0.02 Bcf

## 2. Crude Transportation Fugitive Emissions

None of the sources of fugitive methane emissions in the crude transportation sector are significant. The largest emission rate is from floating roof tanks at 0.05 Bcf per year, representing 98 percent of the total.

Floating Roof Tank Fugitive Emissions

Although floating roof tanks are much more prominent in the crude transport sector than in the production sector, only a small amount of methane remains in crude after the degassing that occurs during field processing and from venting during storage at the field. Radian estimates that vented emissions from transportation and refining sector tanks were only 0.17 percent of vented emissions from production sector tanks. However, 18.5 percent of U.S. oil production comes from offshore, where tank storage and venting are minimized. For this high methane content crude that is first stored onshore, the emission factor is assumed to be the same as for floating roof tanks used in the production sector. These considerations result in an emission factor of 58,965 scf per tank per year. The number of transportation sector floating roof tanks is estimated to be 824; this is based on an Entropy[54] estimate of larger tanks in fluid heavy oil storage service, assuming all are floating roof tanks. The resulting emission estimate is 0.05 Bcf.

Oil Pipeline & Pump Station Fugitive Emissions

The fugitive emission factors for oil pipelines and pumping stations is taken from a PSI study, that estimates oil pipeline emissions to be near zero.[55] The oil pipeline pumping station emission factor is

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[51] Pipeline Systems, Inc., *Annual Methane Emission Estimate of the Natural Gas and Petroleum Systems in the United States*, for ICF Incorporated, December 1989.

[52] *OGJ*, 11/25/96, p.56.

[53] CAPP, 1992

[54] API, *Aboveground Storage Tank Survey*, by Entropy Limited, April 1989.

[55] PSI, 1989.

estimated by PSI to be 25 scf per pipeline-mile per year. The *Oil & Gas Journal*[56] states that oil pipeline mileage was 58,720 miles in 1995. The resulting annual emission rate for pump stations is less than 0.001 Bcf.

### 3. Crude Transportation Combustion Emissions

No activity factors have been found for the two potential sources of combustion emissions identified — engine drivers for pipeline and loading pumps and crude heaters. Table C-2 in Appendix C provides emission factors for these sources that can be used whenever activity factors are available. PSI estimates that nearly all crude pipeline pumps are driven with electric motors.[57] A few pumps in remote locations may use diesel engine drivers or steam turbines with boilers burning fuel oils. Pipeline heaters also probably use fuel oils which have essentially no methane content. Consequently, the combustion emissions from crude transportation pumps and heaters are estimated to be negligible.

## *C. Crude Refining Sector Emissions*

Total annual methane emissions from the refining sector are estimated to be 1.3 Bcf, with no significant sources. Table III-7 summarizes the refining sector emissions by type. As with the previous two industry sectors analyzed, the vented emissions are substantially larger than the other types. Table C-3 in Appendix C provides details of estimated emissions for the refining sector from all of the sources identified.

**Table III-7**
**1995 Crude Refining Sector Emission Estimates by Type of Emission**

| Type of Emission | Emission Estimate (Bcf/yr) | Percent of Total |
|---|---|---|
| Vented | 1.1 | 86% |
| Fugitive | 0.1 | 7% |
| Combustion | 0.1 | 7% |
| Total | 1.3 | 100% |

Very small amounts of methane are present in the gaseous and liquid process streams in refineries. In the refinery fuel gas system, however, methane is more concentrated. This system contains a mixture of light gases that are not valuable enough to be included in the refinery product mix, such as ethane, hydrogen, and methane. Natural gas is frequently added to the waste gases in the fuel gas system to maintain pressure and volume requirements. Consequently, the fuel gas system is the only refinery system where emissions will contain a substantial amount of methane.

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[56] OGJ, 11/25/96, p.56.

[57] Ted Doud, PSI, Personal Communication.

Other process streams that can contain small amounts of methane are the light gaseous overhead streams from the atmospheric distillation towers (the first location where crude is heated to high temperatures and most of the remaining methane in the crude will be released) and the processes where these lighter overhead streams are sent after atmospheric distillation. These downstream processes are referred to as the light ends processes. However, no emission factors have been found for the atmospheric distillation and light ends processes. Heavier product streams, such as gasoline and heating oil, contain essentially no methane.

## 1. Crude Refining Vented Emissions

Total vented methane emissions from the three identified sources in refining operations are estimated to be 1.1 Bcf per year. The two largest sources are system blowdowns and asphalt blowing. Methane vented from refinery tankage is much lower than that from production sector tankage because most of the methane has already been released during production. Table C-3 of Appendix C provides details of all refining vented emissions evaluated.

System Blowdown Vented Emissions

System blowdown emissions of 0.7 Bcf include maintenance preparation venting and releases of gases used to regenerate catalysts and molecular sieves. The emission factor of 136.8 scf per thousand barrels of refinery feed is taken from Radian. The activity factor for 1995 is 14 million barrels (mmbbls) per day of crude fed to refineries.[58]

Asphalt Blowing Vented Emissions

In some refineries, hot air is blown through asphalt recovered from vacuum distillation to change the asphalt's physical characteristics. This operation is estimated by Radian to emit 60 pounds of total hydrocarbon (THC) per ton of asphalt processed. Methane is estimated to be only 1.0 percent of the THCs in asphalt, because the high temperatures to which it has already been exposed have removed most of the methane. These values provide an emission factor of 2,555 scf of methane per 1,000 barrels of asphalt processed. The activity factor of 467,000 barrels of asphalt processed per day is taken from the *Petroleum Supply Annual*[59] report of U.S. asphalt and road oil production. The resulting methane emission rate is 0.4 Bcf per year.

Storage Tank Vented Emissions

Fixed roof tank vented emissions from tanks at refineries are estimated to be 0.01 Bcf per year. These emissions are substantially lower than those from vented tanks in the production sector for two reasons. First, the methane content of crude by the time it leaves the production area is much lower than when it enters production tankage. Second, most of the crude tankage capacity in the refining sector is the floating roof type that releases fugitive emissions as described below in the crude refining fugitive emissions section. The emission factor of 20.6 scf per 1,000 barrels of crude is taken from a 1992 API report.[60] The activity factor is the 1,792,600 barrels per day of heavy crude fed to refineries in 1995, based

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[58] DOE/EIA, *Monthly Energy Review*, December 1997.

[59] DOE/EIA, *Petroleum Supply Annual*, 1996.

[60] API, *No. DR 140*, prepared by Radian, February 1992.

on total crude feed to refineries as reported in DOE's *Monthly Energy Review* and the Radian estimate that 13 percent of feed is heavy crude. Since some heavy crude is stored in floating roof tanks (along with essentially all light crude), this activity factor may be somewhat high.

## 2. Crude Refining Fugitive Emissions

Fugitive emissions from crude oil refining operations are estimated to total 0.09 Bcf per year; 0.07 Bcf of this, or 78 percent of the total, comes from the refinery fuel gas system. Other fugitive sources are cooling towers and wastewater treating.

Fuel Gas System Fugitive Emissions

Annual fugitive methane emissions from an average fuel gas system are estimated to be 439 Mcf per refinery. This value was obtained by estimating the number of valve, flange, and connection components per average fuel gas system and applying standard API component leak rates to each.[61] The numbers of components estimated are 400 valves, 818 flanges, and 3 connectors.[62] The methane content of released gas is estimated to be 45 percent.[63] *The Oil & Gas Journal* reported 163 refineries for 1995. The resulting annual fugitive emission rate for fuel gas systems is 0.07 Bcf.

Floating Roof Tank Fugitive Emissions

The emission factor of 587 scf per tank per year for refinery floating roof tanks was developed using the API *TANKS* program as described earlier in the section on transportation sector emissions from floating roof tanks.[64] The activity factor of 767 floating roof tanks in the refining sector is the sum of the larger tanks in fluid heavy oils service that are listed in the Entropy tank survey.[65] The resulting annual emission rate is less than 0.001 Bcf.

Wastewater Treating Fugitive Emissions

Methane emissions from wastewater treating operations are quite small for two major reasons. First, the hydrocarbons that leak and runoff into the sewer system have little methane content. Second, the gases that are contained in the hydrocarbons have had ample opportunity to release to the atmosphere while in the sewer system. The emission factor of 1.882 scf per thousand barrels of crude feed to refineries is taken from Radian. The 1995 refinery feed rate from EIA's *Monthly Energy Review* is 5.1 billion barrels per year.[66] These factors provide an annual emission rate of 0.01 Bcf.

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[61] API 4638

[62] Consensus of refinery industry experts.

[63] Estimated by calculating the methane content from typical refinery fuel gas heating values.

[64] No allowance is made in the refining sector for the higher methane content of crude produced offshore, which is assumed to have been accounted for in the transportation sector fugitives (see transportation section for details).

[65] API, *Aboveground Storage Tank Survey*, 1989.

[66] EIA, *Monthly Energy Review*, April 1997.

Cooling Tower Fugitive Emissions

Methane emissions from cooling towers, although small, are slightly larger than those from wastewater treatment. This is because recirculated cooling water receives hydrocarbons that have not previously been exposed to the atmosphere in the refinery. The emission factor of 2.4 scf per thousand barrels of crude feed to refineries is taken from Radian. The activity factor for 1995 is the 5.1 billion barrels of crude fed to refineries. The 0.01 Bcf of methane emitted from cooling towers could be categorized as vented emissions as well as fugitive.

## 3. Crude Refining Combustion Emissions

Nearly all of the 0.09 Bcf of methane emissions from combustion in refineries is from the small amount of unburned methane emitted from the stacks of process heaters that typically burn refinery fuel gas. Two other sources, totaling only 0.01 Bcf per year, are flares and gas-fueled drivers for compressors and generators.

Process Heater Combustion Emissions

The estimated annual combustion emissions from the 11 primary processes listed in Table C-3 of Appendix C total 0.08 Bcf. Atmospheric distillation and hydrotreating are the largest sources at approximately 0.02 Bcf each. Emission factors for the 11 processes are taken from Radian. The activity factors, which are the feed rates for the 11 processes, are from *Oil and Gas Journal's December 18, 1995 Worldwide Refining Issue*.

Engine Combustion Emissions

Most of the gas-fueled driver horsepower in refineries today is in the form of combustion gas turbines driving electric generators. The emission factor for gas turbines estimated in the GRI/EPA report on gas industry methane emissions is 0.006 scf per HP-hr.[67] It is estimated that each of the 55 large U.S. refineries with crude charges of 100,000 barrels per day or more has at most 25 MW of turbo generating capacity.[68] These large refinery turbines will deliver a total for 673 million HP-hr per year. Assuming that the 108 smaller refineries each have engines that deliver half the horsepower of the larger refineries, their total annual output will be 661 million HP-hr. This provides a total activity factor of 1,334 HP-hr per year. The combustion turbine capacity allowances used in these estimates is believed to be large enough to capture the small number of smaller compressor internal combustion drivers in use for refrigeration and other process needs. The methane emission estimate resulting from these factors is 0.01 Bcf per year.

Flare Emissions

Methane emissions from refinery flare combustion are estimated to be small (less than 1.0 MMcf per year). The emission factor for refinery flares is estimated by Radian to be 0.8 pounds of VOC per 1,000 barrels of refinery feed. From AP-42, Radian estimates that only 1.0 percent of VOC emissions from refinery flares are unburned methane. Using these values, the methane emission rate is 0.19 scf per 1,000 barrels of crude feed. The refinery feed rate activity factor is 5.1 billion barrels per year.

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[67] EPA/GRI, *Methane Emissions from the Natural Gas Industry, Volume 11: Compressor Driver Exhaust*, by Radian, June 1996.

[68] Consensus of industry review panel.

## IV. POTENTIAL IMPROVEMENTS IN EMISSION ESTIMATES

Review of the results presented in this report indicates that two of the more significant methane emission estimates reported could be improved. The most obvious of the uncertain estimates is apparently the largest single source of emissions — the 26 Bcf from fixed roof tank venting at oil production sites. The availability of *E&P TANK*, the sophisticated model developed by API for estimating emissions from individual vented fixed roof tanks, argues strongly for developing inputs to the model that reasonably represent the characteristics of all U.S. crudes and tank facilities. This improvement can be accomplished by using one of the crude oil reservoir data bases currently available or by using other commercial sources of data on crude oil characteristics by region. These databases provide crude oil characteristics for thousands of reservoirs that can be aggregated regionally prior to running as individual production sites in the *E&P TANK* model.

The emission estimate for chemical injection pumps, which this study found to be a significant source of methane, is another potential area for improvement. The current estimate is that 25 percent of oil industry chemical injection pumps are powered by natural gas. However, many industry experts say that most oil production chemical injection pumps are driven mechanically (i.e., using the walking beam from the oil pump) or with electric motors or compressed air. Generally, the pumps would only be gas-driven at flowing oil wells where walking beams and electricity are not present. The number of wells meeting these criteria is expected to be small, possibly less than five percent.

Additional field testing is currently underway to quantify the methane emission factor for refinery asphalt blowing. In this process, heated air is blown through hot liquefied asphalt to change its physical properties. Since asphalt has been subjected to temperatures as high as 800 to 900 degrees F prior to blowing, much of the original methane would already have escaped by this point. However, the asphalt process can also produce new methane as the hydrocarbons split. Also, the activity factor used includes all asphalt and road oil production, although only a portion of asphalt is blown and none of the road oil is.

## V. OPPORTUNITIES FOR EMISSION REDUCTIONS

Methane is a valuable energy resource as well as a greenhouse gas, therefore many emission control options have direct economic and environmental benefits. Unlike many other sources of greenhouse gases, a few significant sources of methane emissions account for a very large portion of total oil industry methane emissions. Thus, application of a few emission reduction techniques to sources with large losses can result in substantial emission decreases. Some successful strategies for reducing methane emissions in the oil and gas industries have proven to be low cost and profitable. Two examples of profitable emission controls in the oil industry are the addition of vapor recovery systems to oil storage tanks used at oil production sites and the replacement of high-bleed rate pneumatic devices which are used for process controls with low-bleed rate devices. In the case of the vapor recovery units, vented gas that is rich in methane and gas liquids can be compressed and sold, or if no gas gathering system is available, the gas can be flared. Reduction of gas usage by pneumatic devices also can result in additional gas sales at production sites where gas gathering systems are available.

For this report, the economics of options for reducing methane emissions are described for only the "significant" emission sources (those which release 1.0 Bcf per year or more). Of the 70 oil industry methane emission sources analyzed, six production sector sources were found to contribute over 90 percent of the total annual methane emissions estimated for the oil industry.

In this analysis, two levels of methane emission reductions are estimated — the technical potential and the economically feasible. The larger emission reduction estimates are for those that have technical potential and are not constrained by a requirement for an economic return on the costs required to implement the reduction option. The estimates of economically feasible emission reductions have this economic constraint. Economically feasible options for emission sources smaller than 1.0 Bcf per year have been less rigorously evaluated than for the significant sources.

The following paragraphs discuss options that are available to reduce methane emissions from the crude oil production, transportation, and refining sectors of the oil industry. For each of the three sectors, the emissions are further divided into types of emissions — vented, fugitive, and combustion. Upset emissions are added for the production sector.

## *A. Production Sector Emission Reductions*

Technically achievable emission reductions in the oil production sector are an estimated 45 Bcf, or 77 percent of the estimated 58 Bcf total in 1995. Applying a requirement for a reasonable return on the costs of implementing these options reduces the technical potential to an estimated 14 Bcf, or 24 percent of the total. Table V-1 summarizes these estimates of production sector methane emission reductions. The emission reduction options that can provide these decreases are described in the following paragraphs and listed in Table F-1 of Appendix F.

**Table V-1**
**Estimated Methane Emission Reductions from Production Sector Sources**

| Emission Source | Type of Emission | Total Methane Emissions (Bcf/yr) | Methane Emission Reductions | |
|---|---|---|---|---|
| | | | Technical Potential (Bcf/yr) | Economically Feasible (Bcf/yr) |
| **Significant sources** | | | | |
| Storage tanks | Vented | 25.7 | 24.4 | 8.2 |
| Pneumatic devices (high-bleed) | Vented | 19.5 | 17.5 | 4.9 |
| Pneumatic devices (low-bleed) | Vented | 3.6 | 0.4 | 0.2 |
| Chemical injection pumps | Vented | 2.8 | 0.7 | 0 |
| Oil wellheads (light crude) | Fugitive | 1.3 | 0.6 | 0.3 |
| Gas engines | Combustion | 1.4 | 0.1 | 0.1 |
| **Smaller sources total** | All | 4.1 | 1.2 | 0.4 |
| Totals | | 58.4 | 44.9 | 14.1 |

Although detailed economic evaluations of the options for reducing methane emissions from the smaller sources (each emitting less than 1.0 Bcf per year) have not been developed, estimates have been made for emission reduction options that have technical potential and for those that are economically feasible.

### 1. Production Vented Emission Reduction Options

There are four significant vented methane emission sources in the production sector. These four sources — crude storage tanks, high-bleed rate pneumatic devices, low-bleed rate pneumatic devices, and chemical injection pumps — account for 51.6 Bcf of the 53.3 Bcf total vented emissions. The remaining 1.7 Bcf comes from eight lesser sources that vary from near zero to 0.8 Bcf per year. These eight smaller sources include:

- venting on offshore production platforms;
- depressuring of equipment (blowdown) prior to maintenance;
- starting compressors with compressed gas;
- stripper wells;
- venting of oil wells during well completion and workover operations; and
- venting at pipeline pig stations.

Options for reducing vented emissions from each source in the production sector are listed in Table F-1 of Appendix F. Table V-2 provides a summary of these reduction options.

**Table V-2**
**Summary of Vented Emission Reductions from the Production Sector**

| Emission Source | Total Methane Emissions (Bcf/yr) | Methane Emission Reductions | |
|---|---|---|---|
| | | Technical Potential (Bcf/yr) | Economically Feasible (Bcf/yr) |
| **Significant sources** | | | |
| Storage tanks | 25.7 | 24.4 | 8.2 |
| Pneumatic devices (high-bleed) | 19.5 | 17.5 | 4.9 |
| Pneumatic devices (low-bleed) | 3.6 | 0.4 | 0.2 |
| Chemical injection pumps | 2.8 | 0.7 | 0 |
| **Smaller sources total** | 1.7 | 0.2 | <0.1 |
| Totals | 53.3 | 43.2 | 13.3 |

Tank Venting

At an estimated 26 Bcf in 1995, methane emissions from production area tanks is the largest methane source in the oil industry. The most effective options for reducing these emissions are the installation of vapor recovery units (VRUs) and vapor flaring systems. VRUs are used when the recovered gases can be sold for the value of the methane and other hydrocarbons in the vapor. Where a gas gathering system is not available, a flare system can be used to burn the captured gases, thereby reducing the methane released to the atmosphere to the approximately 1.0 percent that is unburned in the flare. Both of these systems are in use in many areas where economics favor capturing and selling the gas that would otherwise be vented, or where tank emission controls are mandated.

The technical potential for methane emission reductions from tank venting is estimated to be the 95 percent effectiveness cited by the Natural Gas STAR program for VRUs. The effectiveness of flare systems are estimated to be essentially the same as for VRU systems. At 95 percent effective, an emission reduction of 24 Bcf should be technically achievable.

Table V-3 provides examples of the returns available for installing VRU systems on production sector crude tanks for several levels of gas emissions. The returns are based on a gas price of $2.00 per Mcf, a 10 percent discount rate, and a five-year service life for the system. The industry rule-of-thumb is to size units at double the average daily emission rate (*i.e.*, gas throughputs are estimated to be 50 percent of the system capacities listed below).

**Table V-3**
**Sample Economic Analyses for VRU Systems**

| Capacity (Mcf/day) | Total Investment ($) | O & M Costs ($/yr) | Value of Gas ($/yr) @ ½ capacity | Payback Period (months) | Return on Investment (%) |
|---|---|---|---|---|---|
| 50 | 34,125 | 6,000 | 18,250 | 38 | 23% |
| 100 | 41,125 | 7,200 | 36,500 | 19 | 66% |
| 200 | 55,125 | 8,400 | 73,000 | 11 | 115% |
| 500 | 77,000 | 12,000 | 182,500 | 6 | 221% |

Source: Natural Gas STAR program, draft Lessons Learned, *Installing Vapor Recovery Units on Crude Oil Storage Tanks.*

For producers who require a payback period of about three years or less, the minimum acceptable gas recovery rate apparent from these examples is 25 Mcf per day (one-half of the 50 Mcf/day capacity). Higher natural gas prices and recognition of the added value of the gas liquids (ethane, propane, butane) in the gas recovered would tend to lower the minimum acceptable gas recovery rate and result in greater emission reductions.

This economic analysis can be used to estimate the economically achievable emission reductions. Assuming that oil storage tanks that are discharged into tank trucks are designed to hold at least two days of production and assuming a gas-to-oil ratio of 50 scf per barrel of crude entering the tank, a tank venting rate of 25 Mcf per day would require 1,000 barrels of tank capacity. The share of total U.S. crude tanks with this capacity or larger is about 35 percent.[69] As estimated in Chapter III, about nine percent of these tanks already have vapor recovery systems. Thus, the potential for emission reduction by installation of economically justified VRUs is estimated to be 32 percent (91 percent of 35 percent) of the 26 Bcf emission estimate for 1995, or 8.2 Bcf.

High-Bleed Pneumatic Device Venting

By definition, high-bleed pneumatic devices are those that vent at least 52 Mcf per year. The EPA average emission factor for these high-bleed units is estimated to be 126 Mcf per year. In all, venting from high-bleed rate pneumatic devices is the second largest source of methane emissions from the oil industry, estimated to be 19.5 Bcf in 1995. The technical potential for reducing these emissions is as high as 90 percent, which may be achieved by replacing the high-bleed devices with low-bleed units or retrofitting them with low-bleed modification kits. These options could eliminate 17.5 Bcf of the estimated 19.5 Bcf emitted each year from high-bleed devices.

The Natural Gas STAR program Best Management Practice Number 1 (BMP 1) for the natural gas industry production sector provides sample economics on the returns that can be available for investing in low-bleed pneumatic devices. Table V-4 shows costs of switching to low-bleed devices, the value of gas conserved, and returns for retrofit and replacement devices. The returns are based on replacing a device that bleeds 250 Mcf per year, a gas price of $2.00 per Mcf, a 10 percent discount rate, and a five-year service life. The retrofit device in this example is a Mizer kit that reduces the bleed rate, but also reduces control sensitivity. In some close control applications the Mizer kit cannot be used and a replacement controller is required to obtain the bleed reductions desired.

**Table V-4**
**Economic Comparison of Retrofit and Replacement High-Bleed Pneumatic Devices**

| Economic Element | Retrofit Controller | Replace Controller |
|---|---|---|
| Implementation costs ($) | $500 | $1,341 |
| Bleed rate reduction (Mcf/yr) | 219 | 228 |
| Value of gas saved ($/yr) | $428 | $456 |
| Payback period (yrs.) | 1.1 | 2.9 |
| Net present value ($) | $1,073 | $300 |
| Internal rate of return (%) | 78% | 18% |

These two examples are based on a 250 Mcf per year bleed rate that is nearly twice that of the average 126 Mcf per year rate for these devices. The results shown in Table V-4 indicate that for producers who require at least a 3-year payout, a replacement controller will be economic only for those devices that bleed greater than average volumes of gas. However, the less costly retrofit option can be

[69] Estimated using the results of API's *Aboveground Storage Tank Survey*, prepared by Entropy Limited, April 1989.

justified for lower bleed rates — down to less than 100 Mcf per year in services where less sensitive process control is acceptable.  Based on these comparisons, the share of methane emissions from pneumatic devices that can be reduce economically is judged to be about 25 percent, or 4.9 Bcf per year.

Low-Bleed Pneumatic Device Venting

Since low-bleed rate pneumatic control devices typically emit 90 percent less than high-bleed devices, there is little room for additional emission reductions from low-bleed devices.  Use of a directed inspection and maintenance (I/M) program to optimize operation and minimize venting of low-bleed devices is judged to have a technical potential for emission reductions of 10 percent, or 0.4 Bcf per year.  The economically feasible reductions are estimated to be half of the technical potential, or 0.2 Bcf per year.

Chemical Injection Pump Venting

At 3.6 Bcf in 1995, methane vented during the normal operation of chemical injection pumps is the third largest source of emissions from the U.S. oil industry.  As in the case of pneumatic devices, the pressurized natural gas that is frequently available at oil production sites is used to drive pumps that inject various chemicals into produced crude oil.  When electricity is available, motors can be used to drive these pumps.  The injected chemicals are used to break oil-water emulsions, inhibit corrosion, dewax paraffins, kill bacteria, and control other processing problems.  The estimated average emission rate for each pump is 122 Mcf per year.  At $2.00 per Mcf the lost gas has an average annual value of $244.  Newer, higher efficiency, pump designs can reduce emissions by up to 25 percent.  At most, this would provide annual savings of only $61.  At a capital and installation cost of $1,500 to $7,500 for a more efficient pump, there is obviously inadequate incentive for replacing injection pumps that have an average bleed rate.  Moreover, since larger pumps with higher bleed rates will be more costly, there is little likelihood that many pump replacements will be economic.  For new installations and replacement of defective pumps where electricity is available, pumps with electric drive motors are the preferred choice.  They cost about 20 percent less than gas or air driven pumps and emit no methane.  For new and necessary replacements where electricity is not available, the current incremental cost of at least $400 for a higher efficiency gas driven pump cannot be economically justified.

The technical potential for emission reductions from chemical injection pumps is the 25 percent decrease in emissions available by replacing existing older designs with higher efficiency units.  These replacements would provide emission reductions of 0.7 Bcf per year.  There are no economically feasible emission reductions at $2.00 per Mcf.

Offshore Platform Venting

Emissions from offshore platform venting have been estimated to be 0.9 Bcf per year based on a MMS study.  As noted previously, most of these emissions likely come from pneumatic devices and chemical injection pumps.  For safety reasons, directed I/M programs are typically in use on platforms and fugitive emissions are minimized relative to onshore operations.  However, the close control of offshore processing operations requires sensitive controllers that use more gas, typically high-bleed devices.  Thus, venting from pneumatic devices is typically a larger part of total emissions.

Changing to electric drives for pneumatic devices and chemical injection pumps on offshore platforms would require more power generation capacity and costly wiring additions on the platforms.  As in the case of onshore facilities, pressurized gas is available and inexpensive compared to the alternatives for driving process control valves and chemical injection pumps. Many producers have switched, or plan to switch, to air-powered pneumatics and controllers offshore for safety reasons — particularly on manned platforms. However, no data is currently available to estimate how many are currently air-powered. Consequently, reductions in vented offshore platform methane emissions are estimated to be restricted to application of directed I/M programs. Offshore platform I/M programs are estimated to provide an emission reduction technical potential of 10 percent, or 0.08 Bcf per year, with a five percent reduction, or 0.04 Bcf per year, economically feasible.

Stripper Well Venting

Stripper well venting can be stopped by simply closing well casing valves. The problem with this emission reduction option is that closing the casing valve will allow gas pressure to build up in the annulus between the production tubing and casing, thereby slowing the oil production rate. Since the emission factor is based on the one-third of total stripper wells estimated to produce an average of one barrel per day, anything that slows the production rate will cause many of these wells to be shut in. Shutting in half of the 142,000 stripper wells that average one barrel per day would reduce U.S. oil production by 71,000 barrels per day, or 26 million barrels per year. This 1.1 percent of total U.S. oil production, valued at $20 per barrel, is worth $520 million per year. The value of the 160 MMcf per year of methane vented at $2.00 per Mcf is $320,000 per year. Additionally, if this gas is not vented at the casing valve, it will be vented from the crude storage tanks, because no vapor recovery units are installed at such small producing facilities. The technical potential for reduction of these emissions is 100 percent, or 0.16 Bcf per year. There is no economic incentive for reducing these emissions.

Other Venting

Technically achievable and economically feasible options for reducing the 0.2 Bcf of methane emissions from the remaining eight minor venting sources are summarized in Table F-1 of Appendix F. The emission factors for each of these sources are so small that use of the available options for reducing emissions on an economic share of the sources is estimated to provide insignificant reductions.

## 2. Production Fugitive Emission Reduction Options

The only significant source of fugitive emissions in the production sector is light crude oil wellheads. The estimated emission rate from 211,127 oil wells (excluding stripper wells) is 1.3 Bcf. This one source is responsible for 45 percent of the 2.9 Bcf total production sector fugitive emissions. The remaining 65 percent comes from 15 smaller sources that vary from zero to 0.6 Bcf per year. Table V-5 summarizes the fugitive emission reductions possible in the production sector.

**Table V-5**
**Summary of Fugitive Emission Reductions from the Production Sector**

| Emission Source | Total Methane Emissions (Bcf/yr) | Methane Emission Reductions | |
|---|---|---|---|
| | | Technical Potential (Bcf/yr) | Economically Feasible (Bcf/yr) |
| **Significant sources** | | | |
| Oil wellheads (light crude) | 1.3 | 0.6 | 0.3 |
| **Smaller sources total** | 1.6 | 0.9 | 0.5 |
| Totals | 2.9 | 1.5 | 0.8 |

Oil Wellheads, Light Crude

At wells producing light crude oil, gas leaks from the valves, flanges, pipe fittings, and polished rod stuffing box on the wellheads. A directed I/M program that concentrates on repairing leaky wellhead components provides an estimated technically achievable emission reduction of 50 percent, or 0.6 Bcf per year. The economically feasible reduction is estimated to be half of the technical potential, or 0.3 Bcf. The cost of a directed I/M programs can be minimized by combining its activities with those normally required to operate and maintain production equipment and systems.

Separators, Heater Treaters and Headers

Separators, heater treaters, and piping headers handling light crude each emit from 0.3 to 0.6 Bcf of methane a year. Totaling 1.4 Bcf a year, these emissions come from the valves, flanges, and small connections on each equipment item and can be reduced by applying a directed I/M program. As with the oil wellheads and smaller emission sources, the leak reductions available from a directed I/M program are judged to be 50 percent for technical potential and 25 percent economically feasible. This results in emission reductions of 0.7 Bcf and 0.4 Bcf, respectively.

Compressors and Pumps

The 0.1 Bcf of methane emitted from compressors and pumps can be reduced through a directed I/M program. The economically achievable emission reductions are estimated to be approximately 70 percent, or 0.07 Bcf.[70] The technical potential for emission reductions is judged to be 80 percent, or 0.08 Bcf.

Floating Roof Tanks

Floating roof tank emissions are only 0.008 Bcf in the production sector because nearly all production area tanks have fixed roofs that are vented. Reduction of vented emissions from fixed roof tanks were discussed earlier in this report section. Emissions from floating roof tanks are categorized as fugitive emissions because the use of floating roofs prevents the intentional venting that occurs with fixed roof tanks. Most of the leakage from floating roof tanks containing crude oil is at the sealing mechanisms where the roof guide poles penetrate the roof and around the circumference of the roof where it meets the vertical tank shell.

For average sized crude storage floating roof tanks, with diameters of approximately 200 feet, the $676 annual value (338 Mcf per year emitted at $2.00 per Mcf) of gas emitted is only a small fraction of the costs involved of adding improved seals. If the tank must be taken out of service, cost estimates for installing improved guide pole seals range from $15,000 to $30,000 depending on tank size. If the tank for some reason is already out of service and clean, the cost of replacing guide pole seals is reduced to $5,000 to $10,000. Improved guide pole seals are estimated to reduce emissions by 99 percent.

The cost range for replacing primary perimeter seals is $120 to $175 per linear foot. For a 200 ft. diameter tank, the cost would range from $75,000 to $110,000. Secondary perimeter seals cost about half as much as the primary seals. Labor costs for installing the perimeter seals are twice the cost of the seals themselves. Because of these high costs and low savings, no economically feasible emission reductions are

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[70] See EPA, *Natural Gas STAR 1996 Workshop and Implementation Guide, BMP III.*

expected to be available from improved roof seals. In locations where such improvements to floating roof crude storage tanks are mandated, there will be a technical potential for emission reductions — estimated to be between 90 and 95 percent. If such mandates applied to half of the floating roof tanks, the technical potential for emission reduction would be only 0.004 Bcf.

Sales Areas

Fugitive emissions totaling 0.08 Bcf per year at the loading docks where crude is placed into tank trucks can be reduced by installing vapor recovery or flare systems. Because most of the tank batteries where crude is loaded are low volume (average methane emission rate of 664 scf per year) and the cost of a vapor recovery system is at least $10,000, the number of locations where these emission reduction options can be economically justified will be a small fraction of the 122 thousand loading docks. A more practicable option for reducing loading emissions is to use a submerged loading procedure in filling tank trucks. Submerged loading, in which the loading nozzle is held below the liquid level during tanker filling, creates fewer emissions than splash loading, which drops the crude into the tanker from above. The cost of installing loading line extensions for submerged loading is estimated to be less than $200 per average sales area. The technical potential for reducing emissions using this option is estimated to reduce sales area emissions 60 percent, or by 0.05 Bcf, compared to splash loading. Since the producer receives no additional revenue for gas that remains in solution in the crude being loaded, the economically feasible emission reduction for submerged loading is estimated to be insignificant.

Other Smaller Sources

Four smaller sources of fugitive emissions that are best controlled by a directed I/M program are listed in Table F-1 of Appendix F which provides a summary of all the production sector emission estimates and options for reducing the emissions. These four sources involve offshore oil platforms in the Gulf of Mexico and in other areas, heavy crude oil wellheads, and oil pipelines. The total leakage of 0.06 Bcf from these sources is primarily from pipe flanges, pipe fittings, and valves. The technical potential for reducing these emissions by use of a well managed direct I/M program is judged to be 50 percent, or 0.03 Bcf. The economically feasible reduction is judged to be half of the technical potential, or 0.01 Bcf. Oil well drilling also releases an insignificant volume of methane from crude spills during operations. Procedures that minimize spills could reduce these minimal emissions.

## 3. Production Combustion Emission Reduction Options

Production combustion methane emissions, resulting from the incomplete burning of methane used as fuel, are estimated to be 1.8 Bcf per year. The combustion occurs in internal combustion engines, which can be reciprocating or turbine types, and process heaters. Gas engines, with 1.4 Bcf emitted per year, are the only significant source of methane from combustion sources in the production sector. The remaining five combustion emission sources have a combined total estimated at 0.4 Bcf. Table V-6 summarizes the combustion emission reductions estimated to be available from the significant source, gas engines, and other smaller sources. In Appendix F, Table F-1 provides a more detailed list of the combustion emissions and the options for reducing them.

**Table V-6**
**Summary of Combustion Emission Reduction from the Production Sector**

| Emission Source | Total Methane Emissions (Bcf/yr) | Methane Emission Reductions | |
|---|---|---|---|
| | | Technical Potential (Bcf/yr) | Economically Feasible (Bcf/yr) |
| **Significant sources** | | | |
| Gas engines | 1.4 | 0.1 | 0.1 |
| **Smaller sources total** | 0.4 | 0.1 | Nil |
| Totals | 1.8 | 0.2 | 0.1 |

Gas Engines

Gas-fueled engines are the only significant source of combustion emissions in the oil production sector, at an estimated 1.4 Bcf per year. In areas where electricity is available, the use of electric motor drives for pumps and compressors will eliminate combustion emissions from engines. Where electric motors are not feasible, engines can be tuned and modified to burn less fuel and to burn catalytically fuels more completely. For larger, new production sites, the use of lean-burn engines may be economic. Several factors indicate that directed I/M programs for engine tuning and the use of minor engine modifications may prove to be the only economic options for emission reductions. For instance, most engines at production sites are relatively small, major engine modifications can be costly, and fuel consumption is not a major cost. Based on engineering judgment, the technical potential for engine emission reductions is judged to be 10 percent, or 0.14 Bcf Economically feasible reductions are judged to be 5 percent, or 0.07 Bcf.

Smaller Sources

The largest combustion emission source for methane among the smaller sources is offshore platforms in the Gulf of Mexico at 0.3 Bcf per year. Since these emissions are primarily from flaring and the engines that drive generators and compressors, the opportunities for emission reductions are limited. Flaring is used to dispose of small gas volumes that cannot be recovered economically because of the platform location relative to gas gathering systems. The technical potential for emission reductions are judged to be no more than 10 percent, or 0.03 Bcf. Economically feasible emission reductions are judged to be insignificant. These same levels of emission reduction are estimated for the remaining four combustion sources that release an estimated total of 0.04 Bcf per year. The four sources are heaters, well drilling, offshore platforms other than in the Gulf of Mexico, and flares. See Table F-1 of Appendix F for estimates of emission reductions by sources and the options available for the reductions.

## 4. Production Upset Emission Reduction Options

Production upsets occur when a process or operation accidentally goes out of control. Examples of upsets are releases from pressure relief valves when pressures rise above safe levels, and oil well blowouts that occur when unanticipated high pressures are encountered while drilling. Table V-7 summarizes methane emissions from production sector upsets.

**Table V-7**
**Summary of Upset Emissions from the Production Sector**

| Emission Source | Total Methane Emissions (Bcf/yr) | Methane Emission Reductions | |
|---|---|---|---|
| | | Technical Potential (Bcf/yr) | Economically Feasible (Bcf/yr) |
| **Significant sources** | None | None | None |
| **Smaller sources total** | 0.3 | Nil | Nil |
| Totals | 0.3 | Nil | Nil |

The 1995 total estimated emissions from production sector upsets are 0.3 Bcf from four small sources: offshore platform emergency shutdowns, pressure relief valves, and oil well blowouts onshore and offshore. Table F-1 in Appendix F provides a summary of the estimated emission rates and emission reduction options for these sources. It is not surprising that emissions from upsets are minor. Since upsets can be costly and hazardous, facility designs and operating and maintenance procedures concentrate on preventing upsets. The largest of the upset emissions is estimated to come from offshore platform emergency shutdowns. For safety reasons, as explained earlier, offshore platforms are designed and operated to be more sensitive to deviations from normal operating conditions than are onshore operations. Thus they may shut down more often than onshore facilities with similar production rates. Since directed I/M programs are currently used on platforms and no other options for emission reductions have been identified, no significant reductions in production upset emissions are judged to be available — either technically or economically.

Pressure Relief Valves

For those few pressure relief valves (PRVs) that leak frequently, a directed I/M program and blowout disks can be used to reduce emissions. Since the 0.007 Bcf annual emission rate from PRVs is so small, both the technical potential and economically feasible emission reductions are estimated to be insignificant from this source.

Well Blowouts

Onshore, where the use of blowout preventers during well drilling is not always mandated, there may be some slight reduction in emissions if more preventers were used. Since blowouts can be costly and hazardous, preventers are typically used at sites where high reservoir pressures are expected to be encountered during drilling. A potential option for reducing emissions from well blowouts is the use of preventers that sense high pressures and shut off automatically, rather than manually. Since the annual emissions from blowouts are quite small and preventive measures are already practiced, the emission reductions from greater use of blowout preventers are judged to be insignificant.

### 5. Summary of Significant Production Sector Methane Emission Reduction Options

For the six significant production sector sources of methane emissions that represent 90 percent of total production sector losses, the technical potential for emission reductions is estimated to total 43.7 Bcf. The economically viable options that are available for emission reductions from five of the significant sources total an estimated 13.7 Bcf. These six significant sources, the available emission reduction options, and the emission reduction estimates are summarized in Table V-8, below.

**Table V-8**
**Summary of Options for Reducing Significant Methane Emissions in the Production Sector**

| Emission Source | Emission Reduction Option | Emission Rate (Bcf/yr) | Emission Reductions | |
|---|---|---|---|---|
| | | | Technical Potential (Bcf/yr) | Economically Feasible (Bcf/yr) |
| **Significant sources** | | | | |
| Storage tanks | Install vapor recovery or flare systems | 25.7 | 24.4 | 8.2 |
| Pneumatic devices (high-bleed) | Replace or modify pneumatic devices | 19.5 | 17.5 | 4.9 |
| Pneumatic devices (low-bleed) | Use directed I/M programs | 3.6 | 0.4 | 0.2 |
| Chemical injection pumps | Use air-drive, motor-drive, or high efficiency pumps | 2.8 | 0.7 | 0.0 |
| Oil wellheads (light crude) | Use directed I/M programs | 1.3 | 0.6 | 0.3 |
| Gas engines | Use electric motors or low emission engines | 1.4 | 0.1 | 0.1 |
| Totals | | 54.3 | 43.7 | 13.7 |

A list of smaller production sector emission sources and the options available to reduce them is provided in Table F-1 of Appendix F.

## *B. Crude Transportation Sector Emission Reductions*

In 1995, the methane emission sources in the crude transportation sector had estimated emissions totaling only 0.31 Bcf, with no sources approaching the 1.0 Bcf level. At 0.26 Bcf, vented emissions account for 84 percent of the total crude transport emissions. Nearly all of the remaining 16 percent are fugitive emissions from floating roof tanks. Table V-9 summarizes estimated emission reductions in the production sector. Table F-2 of Appendix F provides a more detailed account of the emissions and emission reduction options for the crude transportation sector. Combustion emission levels have not been estimated due to a lack of data on emission and activity factors for pipeline pumps and heaters.

**Table V-9**
**Estimated Methane Emission Reductions from Crude Transportation Sector Sources**

| Emission Source | Type of Emission | Total Methane Emissions (Bcf/yr) | Methane Emission Reductions | |
|---|---|---|---|---|
| | | | Technical Potential (Bcf/yr) | Economically Feasible (Bcf/yr) |
| **Significant sources** | None | None | None | None |
| **Smaller sources total** | All | 0.3 | 0.2 | 0.0 |
| Totals | | 0.3 | 0.2 | Nil |

## 1. Crude Transportation Vented Emission Reduction Options

Fixed Roof Tanks

The largest source of vented emissions in the crude transport sector of the oil industry is fixed roof tanks, at 0.11 Bcf. This volume is substantially lower than venting from similar tanks in the oil production sector for two reasons. First, most of the gas has escaped from the crude while stored in fixed roof tanks at the oilfield. Second, most tanks at pipeline and marine terminals are the floating roof type. Vented emissions could be reduced by installing vapor recovery systems; the technical potential for reducing emissions from venting tanks is 90 percent of the emission rate, or 0.10 Bcf. However, since oil pipeline terminals rarely have adjacent natural gas gathering and processing systems, high capital cost vapor recovery systems are not judged to be economic.

Loading Operations

Marine loading vented emissions, along with tank truck and rail tank car loading venting, total 0.14 Bcf. These vented emissions can be reduced by using submerged loading procedures and by installing vapor recovery systems. Submerged loading is estimated to have the technical potential to reduce loading emissions by 60 percent, or 0.08 Bcf, compared to splash loading. Since the crude transporter receives no additional revenue for gas that remains in solution in the crude being loaded, the economically feasible emission reduction for submerged loading is estimated to be insignificant.

Since transportation loading operations are minor sources of emissions, the economics of using vapor recovery systems have not been analyzed. However, the addition of vapor recovery systems at large loading facilities where such systems are not already installed could reduce these emissions.

Other Vented Emissions

Other vented emissions, from pump station maintenance and pipeline pigging operations, are insignificant and should be controlled by use of procedures that minimize spills. Table F-1 in Appendix F provides options for reducing emissions from vented emissions.

### 2. Crude Transportation Fugitive Emission Reduction Options

Fugitive crude transportation emissions total only 0.05 Bcf, mostly from floating roof tanks. No estimated emission reductions have been developed for this small source, since: 1) nearly all of the methane has escaped crude at the production site, 2) floating roof tanks are standard for crude storage at tank farms and terminals, and 3) floating roof tank modifications are costly.

### 3. Crude Transportation Combustion Emission Reduction Options

No estimates of combustion emissions have been developed due to a lack of data on these sources. Industry sources have stated that nearly all crude pipeline pumps are driven by electric motors, providing an activity factor of close to zero. In a few remote locations where electricity is not available, pumps are driven by diesel engines and by steam turbines in which fuel oils are burned to raise steam. No data have been found on the activity and emission factors for oil heaters used to keep crude from becoming too viscous to flow in cold weather. Table F-2 in Appendix F provides options for reducing emissions from combustion emissions.

## *C. Crude Refining Sector Emission Reductions*

There are no significant methane emission sources in the refining sector of the oil industry, although the total losses in 1995 are estimated to be 1.3 Bcf. As with the other production and transportation sectors, vented emissions are the largest share of total refinery emissions — representing 86 percent of total emissions. Fugitive and combustion emissions are each responsible for about seven percent of refinery emissions. Table V-10 summarizes the estimated refinery emission reductions. A more detailed breakdown of these options is provided in Table F-3 of Appendix F.

**Table V-10**
**Estimated Methane Emission Reductions from Crude Refining Sector Sources**

| Emission Source | Type of Emission | Total Methane Emissions (Bcf/yr) | Methane Emission Reductions | |
|---|---|---|---|---|
| | | | Technical Potential (Bcf/yr) | Economically Feasible (Bcf/yr) |
| **Significant sources** | None | None | None | None |
| **Smaller sources total** | All | 1.3 | 0.6 | Nil |
| Totals | | 1.3 | 0.6 | Nil |

## 1. Crude Refining Vented Emission Reduction Options

Process Blowdowns

The largest refining sector vented emission source is processing system blowdowns prior to maintenance activities at 0.7 Bcf per year. System blowdown venting can be reduced by connecting equipment to the refinery blowdown or flare systems when blowdown pressures are adequate to enter these systems. These connections can be permanent or temporary. Alternatively, blowdown gases can be combusted in a gas scavenging and thermal oxidation system. The technical potential for reducing blowdown emissions is judged to be 50 percent of the total, or 0.2 Bcf. No reductions are judged to be economically feasible.

Asphalt Blowing

The hot air discharged from asphalt blowing is the second largest source of refinery emissions, at 0.4 Bcf. These emissions can be reduced by scrubbing or incinerating the air that has contacted the asphalt before releasing it to the atmosphere. The technical potential for emission reductions is estimated to be 0.2 Bcf. No economic reductions are judged to be available.

Fixed Roof Tanks

In some refineries, tank venting occurs because part of the crude is stored in fixed roof tanks rather than floating roof tanks. Venting is greater if the crude has not had normal methane release at the production site. These methane emissions can be reduced by adding vapor recovery systems connected to the refinery fuel gas system or the flare system. Since refinery vented emissions are small and reduction options are relatively expensive, no estimates of economically feasible methane emission reductions are estimated. The technical potential for reductions are judged to be 50 percent of the total 0.013 Bcf emissions, or 0.007 Bcf

## 2. Crude Refining Fugitive Emission Reduction Options

Fuel Gas System

The largest source of fugitive methane emissions in refineries is the fuel gas system which typically contains methane, ethane, and waste refinery gases. Since the emissions are caused by small leaks from hundreds of components, the only reasonable emission reduction option is a directed I/M program. Additionally, most of the potential leaks are located at burner manifolds beneath or adjacent to process heaters. Any gas leaks in these areas will be swept into the combustion chamber of the heater by incoming combustion air for the burners. Furthermore, the existing refinery Leak Detection and Repair (LDAR) program — mandated under numerous federal and state regulations for reducing volatile organic chemicals (VOCs) — requires periodic inspections and repairs of potential leak sources. With fuel gas system leakage estimated at only 0.07 Bcf per year, and considering these existing conditions and programs, no significant emission reductions are estimated for the fuel gas system.

Other Fugitive Emissions

Emissions from floating roof tanks, wastewater systems, cooling towers, and oil processing are relatively insignificant, at a total of 0.02 Bcf per year. Consequently, insignificant emission reduction estimates are estimated. Table F-3 in Appendix F lists several options for emission reductions including:

1) directed I/M programs to complement the LDAR programs 2) reduction of heat exchanger leaks to the water side, and 3) upgrading seals on floating roof tanks.

### 3. Crude Refining Combustion Emission Reduction Options

Gas Fired Heaters

Over 94 percent of the 0.09 Bcf of refinery methane emissions caused by combustion are from gas fired heaters at processing units. The emissions are from unburned methane in the combusted gases. Since incomplete combustion is a function of burner design and burner adjustment, one obvious option for emission reductions is maintenance of optimum burner adjustment as process conditions change. In some cases, replacement of older, less efficient burners with better designs may be necessary. These options apply to 11 of the 13 combustion emission sources listed in Table F-3 of Appendix F. Burner adjustments and improvements are judged to provide methane emission reductions of 10 percent, or 0.01 Bcf, from process heaters. This reduction applies to both the technical potential and economic feasibility.

Other Combustion Emissions

The other two combustion emission sources are engines and flares that have relatively insignificant emission rates, totaling less than 0.01 Bcf per year. Table F-3 in Appendix F provides a summary of the combustion emission rates and options for reducing them. Both the technical and economic potential for emission reductions are estimated to be insignificant.

## VI. CONCLUSIONS

The results of this study indicate that the oil industry is a significant source of methane emissions in the United States — estimated to be 60 Bcf in 1995. However, because of certain industry characteristics, it also appears to be a good place to look for emission reductions. First, unlike other greenhouse gas emissions, methane has value as a fuel and a feedstock. This gives producers an incentive to consider emission reduction methods that conserve gas. Second, the bulk of oil industry methane emissions are concentrated in a few sources; over 90 percent of emissions come from just six sources. Third, there are technologies available to reduce emissions profitably from five of these significant sources. Because of these factors, 24 percent of oil industry methane emissions are estimated to be susceptible to reductions at a profit. The technical potential for emission reductions is judged to be 76 percent of total emissions.

# APPENDICES

# APPENDIX A

## REFERENCES

API (American Petroleum Institute). 1997. *Basic Petroleum Data Book*. January 1997.

CAPP (Canadian Association of Petroleum Producers). 1992. *A Detailed Inventory of CH4 and VOC Emissions from Upstream Oil & Gas Operations in Alberta*. Vols. 1-3. March 1992.

CAPP (Canadian Association of Petroleum Producers). 1993. *Options for Reducing Methane and VOC Emissions from Upstream Oil & Gas Operations*. December 1993.

Department of State. *Climate Action Report*. 1997 Submission of the United States of America Under the United Nations Framework Convention on Climate Change.

Doug, Ted. Personal Communication. Pipeline Systems Incorporated, Walnut Creek, California.

EIA (Energy Information Administration). 1995, *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, Annual Report 1995*. U.S. Department of Energy.

EIA (Energy Information Administration). 1996. *Emissions of Greenhouse Gases in the United States 1995*. U.S. Department of Energy. October 1996.

EIA (Energy Information Administration). 1997. *Monthly Energy Review*. U.S. Department of Energy. April 1997.

Energy Resources Co. 1997. *Atmospheric Emissions from Offshore Oil and Gas Production and Development*. Prepared for EPA. June 1977.

Entropy Limited. 1989. *Aboveground Storage Tank Survey*. Prepared for the American Petroleum Institute. April 1989.

Gallagher, Terry. Personal Communication. Chicago Bridge and Iron.

ICF Kaiser International. 1996. *Estimation of Activity Factors for the Natural Gas Exploration and Production Industry in the United States*. Prepared for the Environmental Protection Agency. August 1996.

MMS (Minerals Management Service). 1995. *Gulf of Mexico Air Quality Study*. Final Report. U.S. Department of Interior. August 1995.

Pipeline Systems Incorporated. 1989 *Annual Methane Emission Estimate of the Natural Gas and Petroleum Systems in the U.S.* Prepared for ICF Incorporated.

Radian. 1977. *Revision of Emission Factors for Petroleum Refining*. Prepared for EPA. October 1977.

Radian. 1992. *Global Emissions of Methane from Petroleum Sources (#DR 140)*. Prepared for API. February 1992.

Radian. 1996. *Methane Emissions from the Natural Gas Industry, V7: Blow and Purge Activities*. Prepared for the Gas Research Institute and EPA. April 1996.

Radian. 1996. *Methane Emissions from the Natural Gas Industry, V11: Compressor Driver Exhaust*. Prepared for GRI and EPA. April 1996.

Radian. 1996. *Methane Emissions from the Natural Gas Industry, V12: Pneumatic Devices*. Prepared for GRI and EPA. April 1996.

Radian. 1996. *Methane Emissions from the Natural Gas Industry, V13: Chemical Injection Pumps*. Prepared for GRI and EPA. April 1996.

Radian. 1996. *Methane Emissions from the U.S. Petroleum Industry*. Draft. Prepared for EPA. June 1996.

Radian. 1996. *Methane and Carbon Dioxide Emissions Estimate for U.S. Petroleum Sources*. Prepared for API. July 1996.

Rayman, Ron. 1997. Personal Communication. Dresser Texsteam, Houston, Texas (manufacturer of chemical injection pumps).

Star Environmental. 1993 *Fugitive Hydrocarbon Emissions from Oil and Gas Production Operations*. Prepared for API. API Document No. 4589. December 1993.

Star Environmental. 1994. *Emission Factors for Oil & Gas Operations*. Prepared for API. API Document No. 4615. December 1994.

Star Environmental. 1996. *Calculation Workbook for Oil and Gas Production Equipment Fugitive Emissions*. Prepared for API. API Document No. 4638. July 1996.

True, Warren R. "U.S. Pipelines Continue Gains into 1996." *Oil & Gas Journal*, 25 November 1996: 39-58.

United States Army Corps of Engineers. *Waterborne Commerce of the United States 1995, Part 5: National Summaries*. 1995

USEPA (U.S. Environmental Protection Agency). 1993. *Anthropogenic Methane Emissions in the U.S.: Estimates for 1990, Report to Congress*. Office of Air and Radiation. EPA-430-R-93-003. April 1993.

USEPA (U.S. Environmental Protection Agency). 1993. *Opportunities to Reduce Anthropogenic Methane Emissions in the United States, Report to Congress.* Office of Air and Radiation. EPA-430-R-93-012. October 1993.

USEPA (U.S. Environmental Protection Agency). 1995. *Compilation of Air Pollution Emission Factors.* Office of Air and Radiation. Research Triangle Park, North Carolina. AP-42. January 1995.

USEPA (U.S. Environmental Protection Agency). 1997. Natural Gas STAR Program, draft Lessons Learned. *Installing Vapor Recovery Units on Crude Oil Storage Tanks*.

USEPA (U.S. Environmental Protection Agency). 1996. *Natural Gas STAR 1996 Workshop and Implementation Guide, Best Management Practice III.*

# Appendix B

| **Industry Reviewers** | |
|---|---|
| **Name** | **Company** |
| **Production** | |
| Bill Freeman | Shell Oil Company |
| Wayne A. Hamilton | Shell Oil Company |
| Vernon H. Schievelbein | Texaco, Inc. |
| John Weust | Marathon Oil Company |
| C. Mark Pike | Exxon Company, USA |
| Vick Newsom | BP/Amoco Corporation |
| Gary Kizior | BP/Amoco Corporation |
| **Refining** | |
| R.J. Aimone | Mobil Corporation |
| A.Y. Tso | Mobil Corporation |

# APPENDIX C

# EMISSION ESTIMATES

**TABLE C-1**
**OIL EXPLORATION & PRODUCTION METHANE EMISSIONS**

| Emission Source No. | Emission Source | Emission Factor | Methane Emission Units | 1995 Activity Factor | Activity Units | Emissions (Bcf/yr) |
|---|---|---|---|---|---|---|
| | | | | | | |
| | **Vented Emissions:** | | | | | |
| 1 | Oil Tanks | 18 | scf of CH4/bbl crude | 1,433.6 | MMbbl/yr (non stripper wells) | 25.662 |
| 2 | Pneumatic Devices, High Bleed | 345 | scfd CH4/device | 157,581 | No. of high-bleed devices | 19.855 |
| 3 | Pneumatic Devices, Low Bleed | 35 | scfd CH4/device | 292,650 | No. of low-bleed devices | 3.687 |
| 4 | Chemical Injection Pumps | 248 | scfd CH4/pump | 31,272 | No. of pumps | 2.831 |
| 5 | Vessel Blowdowns | 78 | scfy CH4/vessel | 205,865 | No. of vessels | 0.016 |
| 6 | Compressor Blowdowns | 3,775 | scf/yr of CH4/compressor | 2,797 | No. of compressors | 0.011 |
| 7 | Compressor Starts | 8,443 | scf/yr. of CH4/compressor | 2,797 | No. of compressors | 0.024 |
| 8 | Stripper wells | 2,345 | scf/yr of CH4/stripper well | 347,538 | No. of stripper wells vented | 0.815 |
| 9 | Well Completion Venting | 733 | scf/completion | 7,627 | Oil well completions | 0.006 |
| 10 | Well Workovers | 96 | scf CH4/workover | 43,086 | Oil well workovers | 0.004 |
| 11 | Pipeline Pigging | 2.40 | scfd of CH4/pig station | 0 | No. of crude pig stations | 0.000 |
| 12 | Offshore Platforms, Gulf of Mexico | 1,283 | scfd CH4/platform | 1,807 | No. of oil platforms | 0.846 |
| 13 | Offshore Platforms, Other U.S. Areas | 1,283 | scfd CH4/platform | 22 | No. of oil platforms | 0.010 |
| | **Total Vented Emissions** | | | | | **53.767** |
| | | | | | | |
| | **Fugitive Emissions:** | | | | | |
| 14 | Offshore Platforms, Gulf of Mexico | 56 | scfd CH4/platform | 1,807 | No. of oil platforms | 0.037 |
| 15 | Offshore Platforms, Other U.S. Areas | 56 | scfd CH4/platform | 22 | No. of oil platforms | 0.000 |
| 16 | Oil Wellheads (heavy crude) | 0.13 | scfd/well | 16,000 | No. of hvy. crude wells * | 0.001 |
| 17 | Oil Wellheads (light crude) | 16.6 | scfd/well | 210,946 | No. of lt. crude wells * | 1.280 |
| 18 | Separators (heavy crude) | 0.15 | scfd CH4/separator | 12,098 | No. of hvy. crude seps. | 0.001 |
| 19 | Separators (light crude) | 14 | scfd CH4/separator | 110,085 | No. of lt. crude seps. | 0.557 |
| 20 | Heater/Treaters (light crude) | 19 | scfd CH4/heater | 83,682 | No. of heater treaters | 0.586 |
| 21 | Headers (heavy crude) | 0.08 | scfd CH4/header | 9,279 | No. of hvy. crude hdrs. | 0.000 |
| 22 | Headers (light crude) | 11 | scfd CH4/header | 84,436 | No. of lt. crude hdrs. | 0.335 |
| 23 | Floating Roof Tanks | 338,306 | scf CH4/floating roof tank/yr. | 24 | No. of floating roof tanks | 0.008 |
| 24 | Compressors | 100 | scfd CH4/compressor | 2,797 | No. of compressors | 0.102 |
| 25 | Large Compressors | 16,360 | scfd CH4/compressor | 0 | No. of large comprs. | 0.000 |
| 26 | Sales Areas | 41 | scf CH4/loading | 1,995,000 | Loadings/year | 0.081 |
| 27 | Pipelines | 0 | scfd of CH4/mile of pipeline | 35,223 | Miles of gathering line | 0.000 |
| 28 | Well Drilling | 0 | scfd of CH4/oil well drilled | 10,682 | No. of oil wells drilled | 0.000 |
| 29 | Battery Pumps | 0.24 | scfd of CH4/pump | 172,345 | No. of battery pumps | 0.015 |
| | **Total Fugitive Emissions** | | | | | **3.003** |
| | | | | | | |
| | **Combustion Emissions:** | | | | | |
| 30 | Gas Engines | 0.08 | scf CH4/HP-hr | 17,634 | MMHP-hr | 1.411 |
| 31 | Heaters | 0.52 | scf CH4/bbl | 2394.4 | MBbl/yr | 0.001 |
| 32 | Well Drilling | 2,453 | scf CH4/well drilled | 10,049 | Oil wells drilled, 1995 | 0.025 |
| 33 | Flares | 20 | scf CH4per Mcf flared | 564,566 | Mcf flared/yr | 0.011 |
| 34 | Offshore Platforms, Gulf of Mexico | 481 | scfd CH4/platform | 1,807 | No. of oil platforms | 0.317 |
| 35 | Offshore Platforms, Other U.S. Areas | 481 | scfd CH4/platform | 22 | No. of oil platforms | 0.004 |
| | **Total Emissions from Combustion** | | | | | **1.769** |
| | | | | | | |
| | **Process Upset Emissions:** | | | | | |
| 36 | Platform Emergency Shutdowns | 256,888 | scfy/platform | 1,829 | No. of platforms | 0.470 |
| 37 | Pressure Relief Valves | 35 | scf/yr/PR valve | 200,000 | No. of PR valves | 0.007 |
| 38 | Well Blowouts Offshore | 5.0 | MMscf/blowout | 2.25 | No. of blowouts/yr | 0.011 |
| 39 | Well Blowouts Onshore | 2.5 | MMscf/blowout | 33.5 | No. of blowouts/yr | 0.084 |
| | **Total Emissions from Upsets** | | | | | **0.572** |
| | | | | | | |
| | **Total CH4 Emissions, Bcf** | | | | | **59.111** |
| | Share of total from sources higher than 1.0 Bcf of CH4 | | | | | 0.926 |
| | | | | | | |
| | Annual production, 1995 | | | 2394.4 | MM Bbl/yr. | |
| | Percent heavy crude API<$20^{o}$ | | | 12.83% | % of annual prod. | |
| | Total producing oil wells 1995 | | | 574,483 | No. of wells | |
| | Percent heavy oil wells, API<$20^{o}$ | | | 6.97% | % of total wells | |
| | Total stripper oil wells 1995 | | | 434,422 | No. of stripper wells | |
| | | | | | | |
| | * Number of oil wells, less number of stripper wells that are vented | | | | | |

| TABLE C-2<br>CRUDE TRANSPORTATION METHANE EMISSIONS | | | | | | |
|---|---|---|---|---|---|---|
| **Emission Source No.** | **Emission Source** | **Emission Factor** | **Emission Units** | **1995 Activity Factor** | **Activity Units** | **Emissions (Bcf/yr)** |
| | | | | | | |
| | **Vented Emissions:** | | | | | |
| 1 | Tanks | 0.021 | scf CH4/yr/bbl of crude delivered to refineries | 5,100 | MMbbl crude feed/yr | 0.105 |
| 2 | Truck Loading | 0.520 | scf CH4/yr/bbl of crude transported by truck | 70 | MMbbl crude feed/yr | 0.036 |
| 3 | Marine Loading | 2.544 | scf CH4/1000 gal.crude marine loadings | 38,666,930 | 1000 gal./yr loaded | 0.098 |
| 4 | Rail Loading | 0.520 | scf CH4/yr/bbl of crude transported by rail | 6.6 | MMbbl.crude by rail/yr | 0.003 |
| 5 | Pump Station Maintenance | 36.80 | scf CH4/station/yr | 587 | No. of pump stations | 0.000 |
| 6 | Pipeling Pigging | 39 | scfd of CH4/pig station | 1,174 | No. of pig stations | 0.017 |
| | **Total Vented Emissions** | | | | | **0.259** |
| | | | | | | |
| | **Fugitive Emissions:** | | | | | |
| 7 | Pump Stations | 25 | scfCH4/mile/yr. | 58,720 | No. of miles of crude p/l | 0.001 |
| 8 | Pipelines | 0 | scf CH4/bbl crude transported by pipeline | 6,952 | MM bbl crude piped | 0.000 |
| 9 | Floating Roof Tanks | 58,965 | scf CH4/floating roof tank/yr. | 824 | No. of floating roof tanks | 0.049 |
| | **Total Fugitive Emissions** | | | | | **0.050** |
| | | | | | | |
| | **Combustion Emissions:** | | | | | |
| 10 | Pump Engine Drivers | 0.24 | scf CH4/hp-hr | NA | No. of hp-hrs | NA |
| 11 | Heaters | 0.521 | scf CH4/bbl.burned | NA | No. of bbl. burned | NA |
| | **Total Combustion Emissions** | | | | | **0.000** |
| | | | | | | |
| | **Total CH4 Emissions, Bcf** | | | | | **0.309** |
| | Share of total from sources higher than 1.0 Bcf of CH4 | | | | | **0.0%** |

| TABLE C-3<br>REFINERY METHANE EMISSIONS | | | | | | |
|---|---|---|---|---|---|---|
| **Emission Source No.** | **Emission Source** | **Emission Factor** | **Emission Units** | **1995 Activity Factor** | **Activity Units** | **Emissions (Bcf/yr)** |
| | | | | | | |
| | **Vented Emissions:** | | | | | |
| 1 | Tanks | 20.6 | scfCH4/Mbbl | 1,793 | Mbbl/cd heavy crude feed | 0.013 |
| 2 | System Blowdowns | 137 | scfCH4/Mbbl | 13,972 | Mbbl/cd refinery feed | 0.698 |
| 3 | Asphalt Blowing | 2,555 | scfCH4/Mbbl | 467 | Mbbl/cd production | 0.435 |
| | **Total Vented Emissions** | | | | | **1.147** |
| | | | | | | |
| | **Fugitive Emissions:** | | | | | |
| 4 | Fuel Gas System | 439 | McfCH4/refinery/yr | 165 | refineries | 0.072 |
| 5 | Floating Roof Tanks | 587 | scf CH4/floating roof tank/yr. | 767 | No. of floating roof tanks | 0.0005 |
| 6 | Wastewater Treating | 1.88 | scfCH4/Mbbl | 13,972 | Mbbl/cd refinery feed | 0.010 |
| 7 | Cooling Towers | 2.36 | scfCH4/Mbbl | 13,972 | Mbbl/cd refinery feed | 0.012 |
| | **Total Fugitive Emissions** | | | | | **0.095** |
| | | | | | | |
| | **Combustion Emissions:** | | | | | |
| 8 | Atmospheric Distillation | 3.61 | scfCH4/Mbbl | 13,972 | Mbbl/cd refinery feed | 0.018 |
| 9 | Vacuum Distillation | 3.61 | scfCH4/Mbbl | 6,178 | Mbbl/cd feed | 0.008 |
| 10 | Thermal Operations | 6.02 | scfCH4/Mbbl | 1,722 | Mbbl/cd feed | 0.004 |
| 11 | Catalytic Cracking | 5.17 | scfCH4/Mbbl | 4,808 | Mbbl/cd feed | 0.009 |
| 12 | Catallytic Reforming | 7.22 | scfCH4/Mbbl | 3,297 | Mbbl/cd feed | 0.009 |
| 13 | Catalytic Hydrocracking | 7.22 | scfCH4/Mbbl | 1,216 | Mbbl/cd feed | 0.003 |
| 14 | Hydrorefining | 2.17 | scfCH4/Mbbl | 1,707 | Mbbl/cd feed | 0.001 |
| 15 | Hydrotreating | 6.50 | scfCH4/Mbbl | 7,461 | Mbbl/cd feed | 0.018 |
| 16 | Alkylation/Polymerization | 12.6 | scfCH4/Mbbl | 1,061 | Mbbl/cd feed | 0.005 |
| 17 | Aromatics/Isomeration | 1.80 | scfCH4/Mbbl | 825 | Mbbl/cd feed | 0.001 |
| 18 | Lube Oil Processing | 0.00 | scfCH4/Mbbl | 197 | Mbbl/cd feed | 0.000 |
| 19 | Engines | 0.006 | scfCH4/hp-hr | 1,334 | MMhp-hr/yr | 0.008 |
| 20 | Flares | 0.189 | scfCH4/Mbbl | 13,972 | Mbbl/cd refinery feed | 0.001 |
| | **Total Combustion Emissions** | | | | | **0.084** |
| | | | | | | |
| | **Total CH4 Emissions, Bcf** | | | | | **1.325** |
| | Share of total from sources higher than 1.0 Bcf of CH4 | | | | | **0.0%** |

# APPENDIX D

## COMPARISON OF EMISSION ESTIMATES

| TABLE D-1<br>COMPARISON OF OIL EXPLORATION & PRODUCTION<br>METHANE EMISSION ESTIMATES | | | | |
|---|---|---|---|---|
| **Emission Source No.** | **Emission Source** | **Current Emission Estimate (Bcf/yr)** | **Radian Emission Estimate[1] (BCF/yr)** | **Other Emission Estimates[2] (Bcf/yr)** |
| | | | | |
| | **Vented Emissions:** | | | |
| 1 | Oil Tanks | 25.662 | 30.235 | |
| 2 | Pneumatic Devices, High Bleed[3] | 19.855 | 14.734 | |
| 3 | Pneumatic Devices, Low Bleed | 3.687 | | |
| 4 | Chemical Injection Pumps | 2.831 | 11.323 | |
| 5 | Vessel Blowdowns | 0.016 | 0.016 | |
| 6 | Compressor Blowdowns | 0.011 | 0.011 | |
| 7 | Compressor Starts | 0.024 | 0.024 | |
| 8 | Stripper Wells | 0.815 | | |
| 9 | Well Completion Venting | 0.006 | 0.005 | |
| 10 | Well Workovers | 0.004 | 0.004 | |
| | Oil Wellheads (heavy crude) | | 0.012 | |
| | Oil Wellheads (light crude) | | 3.879 | |
| 11 | Pipeline Pigging | 0.000 | | |
| 12 | Offshore Platforms, Gulf of Mexico | 0.846 | | |
| 13 | Offshore Platforms, Other U.S. Areas | 0.010 | | |
| | **Total Vented Emissions** | **53.767** | **56.352** | |
| | | | | |
| | **Fugitives Emissions:** | | | |
| 14 | Offshore Platforms, Gulf of Mexico | 0.037 | 1.163 | |
| 15 | Offshore Platforms, Other U.S. Areas | 0.000 | 0.009 | |
| 16 | Oil Wellheads (heavy crude) | 0.001 | | |
| 17 | Oil Wellheads (light crude) | 1.280 | | |
| 18 | Separators (heavy crude) | 0.001 | 0.004 | |
| 19 | Separators (light crude) | 0.557 | 2.062 | |
| 20 | Heater/Treaters (light crude) | 0.586 | 1.644 | |
| 21 | Headers (heavy crude) | 0.000 | 0.002 | |
| 22 | Headers (light crude) | 0.335 | 6.250 | |
| 23 | Floating Roof Tanks | 0.008 | 0.681 | |
| 24 | Compressors | 0.102 | 0.011 | |
| 25 | Large Compressors | 0.000 | 11.585 | |
| 26 | Sales Areas | 0.081 | 0.080 | |
| 27 | Pipelines | 0.000 | 0.725 | |
| 28 | Well Drilling | 0.000 | | |
| 29 | Battery Pumps | 0.015 | | |
| | **Total Fugitive Emissions** | **3.003** | **24.216** | **4.232** |
| | | | | |
| | **Combustion Emissions:** | | | |
| 30 | Gas Engines | 1.411 | 4.232 | |
| 31 | Heaters | 0.001 | 0.001 | |
| 32 | Well Drilling | 0.025 | 0.001 | |
| 33 | Flares | 0.011 | | |
| 34 | Offshore Platforms, Gulf of Mexico | 0.317 | | |
| 35 | Offshore Platforms, Other U.S. Areas | 0.004 | | |
| | **Total Emissions from Combustion** | **1.769** | **4.234** | |
| | | | | |
| | **Upsets:** | | | |
| 36 | Platform Emergency Shutdowns | 0.470 | 0.286 | |
| 37 | Pressure Relief Valves | 0.007 | 0.007 | |
| 38 | Well Blowouts Offshore | 0.011 | 0.001 | |
| 39 | Well Blowouts Onshore | 0.084 | 0.008 | |
| | **Total Emissions from Upsets** | **0.572** | **0.302** | |
| | | | | |
| | **Total CH4 Emissions, Bcf** | **59.111** | **85.104** | |

[1]The Radian estimates are updated using 1995 activity factors where available.

[2]Estimates in this column are from API DR 140.

[3]The current study separates high bleed and low bleed devices. The Radian estimate is for all pneumatic devices.

**TABLE D-2**
**COMPARISON OF CRUDE TRANSPORTATION**
**METHANE EMISSION ESTIMATES**

| Emission Source No. | Emission Source | Current Emission Estimate (Bcf/yr) | Radian Emission Estimate[1] (BCF/yr) | Other Emission Estimates[2] (Bcf/yr) | |
|---|---|---|---|---|---|
| | | | | | |
| | **Vented Emissions:** | | | | |
| 1 | Tanks | 0.105 | 0.188 | | |
| 2 | Truck Loading | 0.036 | 0.034 | 0.023 | |
| 3 | Marine Loading | 0.098 | 1.428 | 0.312 | 0.677 |
| 4 | Rail Loading | 0.003 | 0.002 | 0.002 | |
| 5 | Pump Station Maintenance | 0.000 | 0 | | |
| 6 | Pipeling Pigging | 0.017 | | | |
| | **Total Vented Emissions** | **0.259** | **1.651** | | |
| | | | | | |
| | **Fugitive Emissions:** | | | | |
| 7 | Pump Stations | 0.001 | 0.001 | | |
| 8 | Pipelines | 0.000 | 0 | | |
| 9 | Floating Roof Tanks | 0.049 | | | |
| | **Total Fugitive Emissions** | **0.050** | **0.001** | | |
| | | | | | |
| | **Combustion Emissions:** | | | | |
| 10 | Pump Engine Drivers | NA | | | |
| 11 | Heaters | NA | | | |
| | **Total Combustion Emissions** | **0.000** | **0** | | |
| | | | | | |
| | | | | | |
| | **Total CH4 Emissions, Bcf** | **0.309** | **1.65** | | |
| | | | | | |

[1]The Radian estimates are updated using 1995 activity factors where available.

[2]Estimates in the first column are from API DR 140. Estimates in the second column are from API's *Methane and Carbon Dioxide Emission Estimates from U.S. Petroleum Sources*.

**TABLE D-3**
**COMPARISON OF REFINERY**
**METHANE EMISSION ESTIMATES**

| Emission Source No. | Emission Source | Current Emission Estimate (Bcf/yr) | Radian Emission Estimate[1] (BCF/yr) |
|---|---|---|---|
| | | | |
| | **Vented Emissions:** | | |
| 1 | Tanks | 0.013 | 0.103 |
| 2 | System Blowdowns | 0.698 | 0.684 |
| 3 | Asphalt Blowing | 0.435 | 0.167 |
| | **Total Vented Emissions** | **1.147** | **0.954** |
| | | | |
| | **Fugitive Emissions:** | | |
| 4 | Fuel Gas System | 0.072 | 3.260 |
| 5 | Floating Roof Tanks | 0.0005 | |
| 6 | Wastewater Treating | 0.010 | 0.009 |
| 7 | Cooling Towers | 0.012 | 0.012 |
| | **Total Fugitive Emissions** | **0.095** | **3.281** |
| | | | |
| | **Combustion Emissions:** | | |
| 8 | Atmospheric Distillation | 0.018 | 0.018 |
| 9 | Vacuum Distillation | 0.008 | 0.009 |
| 10 | Thermal Operations | 0.004 | 0.004 |
| 11 | Catalytic Cracking | 0.009 | 0.009 |
| 12 | Catallytic Reforming | 0.009 | 0.009 |
| 13 | Catalytic Hydrocracking | 0.003 | 0.003 |
| 14 | Hydrorefining | 0.001 | 0.001 |
| 15 | Hydrotreating | 0.018 | 0.019 |
| 16 | Alkylation/Polymerization | 0.005 | 0.005 |
| 17 | Aromatics/Isomeration | 0.001 | 0.000 |
| 18 | Lube Oil Processing | 0.000 | 0.000 |
| 19 | Engines | 0.008 | 0.162 |
| 20 | Flares | 0.001 | 0.001 |
| | **Total Combustion Emissions** | **0.084** | **0.240** |
| | | | |
| | | | |
| | **Total CH4 Emissions, Bcf** | **1.325** | **4.475** |
| | | | |

[1]The Radian estimates are updated using 1995 activity factors where available.

# APPENDIX E

## Summary of Total Hydrocarbon Emissions from Gulf of Mexico OCS Oil and Gas Platforms

| Emission Source | Number of Sources | Total Hydrocarbon (tons/yr) |
|---|---|---|
| Equipment | | |
| Internal Combustion Engines | | |
| Diesel Reciprocating (<600 hp) | 2,642 | 177.6 |
| Natural Gas Turbine | 346 | 848.6 |
| Diesel Turbine | 5 | <1 |
| Natural Gas Reciprocating | 2,272 | 37,293 |
| Diesel Large Bore (>600 hp) | 48 | 8.1 |
| External Combustion | | |
| Natural Gas Boilers | 668 | 18.3 |
| Diesel Boiler | 1 | <1 |
| Flares | | |
| Ignited Flares | 78 | 215 |
| Non-ignited Flares | 124 | 40,120 |
| Vents | 552 | 189,344 |
| Crude Tanks | 632 | 10,599 |
| Diesel Tanks | 1,101 | 47 |
| Amine | 5 | -- |
| Platform Fugitives | 1,513 | 9,139 |
| **Total Platform Emissions** | | **287,810** |
| SUMMARY BY TYPE OF EMISSION | | |
| Fugitive | | 9,139 |
| Vented | | 199,990 |
| Combustion | | 78,810 |
| **TOTAL** | | **287,810** |

Source: Gulf of Mexico Air Quality Study, Final Report, U.S. Department of Interior, Minerals Management Service. August 1995.

# APPENDIX F

# EMISSION REDUCTIONS

**TABLE F-1**
**OIL EXPLORATION & PRODUCTION METHANE EMISSIONS**
**OPTIONS FOR REDUCING EMISSIONS**

| Emission Source No. | Emission Source | Emissions (Bcf/yr) | Emission Reductions (Bcf/yr) | | Economically Feasible Options for Emission Reductions | Emission Reduction Options with Technical Potential |
|---|---|---|---|---|---|---|
| | | | Economic | Technical | | |
| | **Vented Emissions:** | | | | | |
| 1 | Oil Tanks | 25.662 | 8.21 | 24.38 | Add vapor recovery system or flare system (with or without gas boot) pressure vacuum valves | Same as economic options, cool sales oil |
| 2 | Pneumatic Devices, High Bleed | 19.855 | 4.87 | 17.54 | Low bleed devices, low bleed attachments, instrument air system | |
| 3 | Pneumatic Devices, Low Bleed | 3.687 | 0.18 | 0.36 | Directed I/M program | Directed I/M program |
| 4 | Chemical Injection Pumps | 2.831 | 0.00 | 0.71 | Directed I/M program | Use higher efficiency pumps, electric drives |
| 5 | Vessel Blowdowns | 0.016 | 0.00 | 0.00 | Connect to an existing vapor recovery or flare system | Connect to vapor recovery or flare system, transfer gas with a portable compressor prior to blowdown |
| 6 | Compressor Blowdowns | 0.011 | 0.00 | 0.00 | Connect to an existing vapor recovery or flare system | Connect to vapor recovery or flare system, transfer gas with a portable compressor prior to blowdown |
| 7 | Compressor Starts | 0.024 | 0.00 | 0.00 | None | Switch to air or hydraulic starting fluid |
| 8 | Stripper Wells | 0.815 | 0.00 | 0.16 | None | Close casing valves |
| 9 | Well Completion Venting | 0.006 | 0.00 | 0.00 | Operating procedures to minimize venting | Operating procedures to minimize venting |
| 10 | Well Workovers | 0.004 | 0.00 | 0.00 | Operating procedures to minimize venting | Operating procedures to minimize venting |
| 11 | Pipeline Pigging | 0.000 | 0.00 | 0.00 | recovery station | Transfer ejected oil with pump |
| 12 | Offshore Platforms, Gulf of Mexico | 0.846 | 0.04 | 0.08 | Directed I/M program | Use electric drives for venting devices, install gas collection and incineration systems |
| 13 | Offshore Platforms, Other U.S. Areas | 0.010 | 0.00 | 0.00 | Use electric drives for venting devices | Install gas collection and incineration systems |
| | **Total Vented Emissions** | **53.767** | **13.31** | **43.23** | | |
| | **Fugitives Emissions (Leaks):** | | | | | |
| 14 | Offshore Platforms, Gulf of Mexico | 0.037 | 0.009 | 0.018 | Directed I/M program | Add leak collection & incineration system |
| 15 | Offshore Platforms, Other U.S. Areas | 0.000 | 0.000 | 0.000 | Directed I/M program | Add leak collection & incineration system |
| 16 | Oil Wellheads (heavy crude) | 0.001 | 0.000 | 0.000 | Directed I/M program | Directed I/M program |
| 17 | Oil Wellheads (light crude) | 1.280 | 0.320 | 0.641 | Directed I/M program | Directed I/M program |
| 18 | Separators (heavy crude) | 0.001 | 0.000 | 0.000 | Directed I/M program | Directed I/M program |
| 19 | Separators (light crude) | 0.557 | 0.139 | 0.278 | Directed I/M program | Directed I/M program |
| 20 | Heater/Treaters (light crude) | 0.586 | 0.132 | 0.264 | Directed I/M program | Directed I/M program |
| 21 | Headers (heavy crude) | 0.000 | 0.000 | 0.000 | Directed I/M program | Directed I/M program |
| 22 | Headers (light crude) | 0.335 | 0.084 | 0.167 | Directed I/M program | Directed I/M program |
| 23 | Floating Roof Tanks | 0.008 | 0.000 | 0.004 | Directed I/M program | Upgrade guide poles and their seals, upgrade |
| 24 | Compressors | 0.102 | 0.071 | 0.082 | Directed I/M program | Directed I/M program, upgrade seals on rods and |
| 25 | Large Compressors | 0.000 | 0.000 | 0.000 | Directed I/M program | shafts |
| 26 | Sales Areas | 0.081 | 0.000 | 0.049 | None | Add vapor recovery system or flare system at loading docks, use submerged loading |
| 27 | Pipelines | 0.000 | 0.000 | 0.000 | Directed I/M program | More extensive use of directed I/M programs |
| 28 | Well Drilling | 0.000 | 0.000 | 0.000 | Procedures to minimize leakage | |
| 29 | Battery Pumps | 0.015 | 0.004 | 0.005 | Directed I/M program, upgrade seals on rods and shafts | |
| | **Total Fugitive Emissions** | **3.003** | **0.761** | **1.509** | | |
| | **Combustion Emissions:** | | | | | |
| 30 | Gas Engines | 1.411 | 0.071 | 0.141 | Directed I/M program | engines for efficient combustion, add catalytic converters |
| 31 | Heaters | 0.001 | 0.000 | 0.000 | Replace old burners with more efficient | Use waste heat exchangers to reduce fuel use |
| 32 | Well Drilling | 0.025 | 0.000 | 0.002 | Directed I/M program | engines for efficient combustion, add catalytic converters |
| 33 | Flares | 0.011 | 0.000 | 0.001 | Reduce gas flow to pilots | Replace flare pilots with igniters |
| 34 | Offshore Platforms, Gulf of Mexico | 0.317 | 0.000 | 0.032 | Directed I/M program | with igniters |
| 35 | Offshore Platforms, Other U.S. Areas | 0.004 | 0.000 | 0.001 | Directed I/M program | Modify engines, use turbines, replace flare pilots |
| | **Total Emissions from Combustion** | **1.769** | **0.071** | **0.177** | | |
| | **Upsets:** | | | | | |
| 36 | Platform Emergency Shutdowns | 0.470 | 0.000 | 0.000 | None | None |
| 37 | Pressure Relief Valves | 0.007 | 0.000 | 0.000 | Directed I/M program, blowout disks | Directed I/M program, add blowout disks |
| 38 | Well Blowouts Offshore | 0.011 | 0.000 | 0.000 | None | preventers |
| 39 | Well Blowouts Onshore | 0.084 | 0.000 | 0.000 | Increase use of blowout preventers | preventers |
| | **Total Emissions from Upsets** | **0.572** | **0.000** | **0.000** | | |
| | **Total CH4 Emissions, Bcf** | **59.11** | **14.14** | **44.92** | | |

**TABLE F-2**
**CRUDE TRANSPORTATION METHANE EMISSIONS**
**OPTIONS FOR REDUCING EMISSIONS**

| | | | Emission Reductions (Bcf/yr) | | | |
|---|---|---|---|---|---|---|
| **Emission Source No.** | **Emission Source** | **Emissions (Bcf/yr)** | **Economic** | **Technical** | **Economically Feasible Options for Emission Reductions** | **Emission Reduction Options with Technical Potential** |
| | **Vented Emissions:** | | | | | |
| 1 | Tanks | 0.105 | 0.000 | 0.095 | None | Floating roof tanks, vapor recovery system, pressure-vacuum valves |
| 2 | Truck Loading | 0.036 | 0.000 | 0.022 | Use submerged loading | Use submerged loading, add vapor recovery system |
| 3 | Marine Loading | 0.098 | 0.000 | 0.059 | Use submerged loading | Use submerged loading, add vapor recovery system |
| 4 | Rail Loading | 0.003 | 0.000 | 0.002 | Use submerged loading | Use submerged loading, add vapor recovery system |
| 5 | Pump Station Maintenance | 0.000 | 0.000 | 0.000 | Directed I/M program | Install pump system to transfer oil contents |
| 6 | Pipeling Pigging | 0.017 | 0.000 | 0.000 | Minimize oil volume ejected at recovery station | Install pump system to transfer ejected oil |
| | **Total Vented Emissions** | **0.259** | **0.000** | **0.177** | | |
| | **Fugitive Emissions:** | | | | | |
| 7 | Pump Stations | 0.001 | 0.000 | 0.000 | Directed I/M program | Upgrade pump seals |
| 8 | Pipelines | 0.000 | 0.000 | 0.000 | Directed I/M program | Inspect lines with leak detecting pigs |
| 9 | Floating Roof Tanks | 0.049 | 0.000 | 0.000 | Directed I/M program | Upgrade guide poles and their seals, upgrade perimeter seals |
| | **Total Fugitive Emissions** | **0.050** | **0.000** | **0.000** | | |
| | **Combustion Emissions:** | | | | | |
| 10 | Pump Engine Drivers | NA | 0.000 | 0.000 | Modify engines, add catalytic converters, use electric motors | Use lean burn engines or electric motors, modify engines for efficient combustion, add catalytic converters |
| 11 | Heaters | NA | 0.000 | 0.000 | Directed I/M program | Replace burners with higher efficiency models |
| | **Total Combustion Emissions** | **0.000** | **0.000** | **0.000** | | |
| | **Total CH4 Emissions, Bcf** | **0.309** | **0.000** | **0.177** | | |

**TABLE F-3**
**REFINERY METHANE EMISSIONS**
**OPTIONS FOR REDUCING EMISSIONS**

| | | | **Emission Reductions (Bcf/yr)** | | | |
|---|---|---|---|---|---|---|
| **Emission Source No.** | **Emission Source** | **Emissions (Bcf/yr)** | **Economic** | **Technical** | **Economically Feasible Options for Emission Reductions** | **Emission Reduction Options with Technical Potential** |
| | | | | | | |
| | **Vented Emissions:** | | | | | |
| 1 | Fixed Roof Tanks | 0.013 | 0.000 | 0.007 | None | Add vapor recovery system, flare system, activated charcoal, pressure/vacuum valves |
| 2 | System Blowdowns | 0.698 | 0.000 | 0.349 | Attach to existing refinery blowdown system | Connect to vapor recovery or flare system, transfer gas with a portable compressor prior to blowdown |
| 3 | Asphalt Blowing | 0.435 | 0.000 | 0.218 | None | Use vapor scrubber, vapor incinerator |
| | **Total Vented Emissions** | **1.147** | **0.000** | **0.573** | | |
| | | | | | | |
| | **Fugitive Emissions:** | | | | | |
| 4 | Fuel Gas System | 0.072 | 0.000 | 0.000 | Directed I/M program | |
| 5 | Floating Roof Tanks | 0.000 | 0.000 | 0.000 | Directed I/M program | Upgrade guide poles and their seals, upgrade perimeter seals |
| 6 | Wastewater Systems | 0.010 | 0.000 | 0.000 | Directed I/M program to reduce spills | Reduce leaks in oil-to-water heat exchangers, install vapor recovery system |
| 7 | Cooling Towers | 0.012 | 0.000 | 0.000 | None | Reduce oil-to-water leaks in heat exchangers |
| | **Total Fugitive Emissions** | **0.095** | **0.000** | **0.000** | | |
| | | | | | | |
| | **Combustion Emissions:** | | | | | |
| 8 | Atmospheric Distillation | 0.018 | 0.002 | 0.002 | Maintain proper burner adjustment | Use high efficiency burners, air preheater, computer controls |
| 9 | Vacuum Distillation | 0.008 | 0.001 | 0.001 | Maintain proper burner adjustment | Use high efficiency burners, air preheater, computer controls |
| 10 | Thermal Operations | 0.004 | 0.000 | 0.000 | Maintain proper burner adjustment | Use high efficiency burners, air preheater, computer controls |
| 11 | Catalytic Cracking | 0.009 | 0.001 | 0.001 | Maintain proper burner adjustment | Use high efficiency burners, air preheater, computer controls |
| 12 | Catalytic Reforming | 0.009 | 0.001 | 0.001 | Maintain proper burner adjustment | Use high efficiency burners, air preheater, computer controls |
| 13 | Catalytic Hydrocracking | 0.003 | 0.000 | 0.000 | Maintain proper burner adjustment | Use high efficiency burners, air preheater, computer controls |
| 14 | Hydrorefining | 0.001 | 0.000 | 0.000 | Maintain proper burner adjustment | Use high efficiency burners, air preheater, computer controls |
| 15 | Hydrotreating | 0.018 | 0.002 | 0.002 | Maintain proper burner adjustment | Use high efficiency burners, air preheater, computer controls |
| 16 | Alkylation/Polymerization | 0.005 | 0.000 | 0.000 | Maintain proper burner adjustment | Use high efficiency burners, air preheater, computer controls |
| 17 | Aromatics/Isomeration | 0.001 | 0.000 | 0.000 | Maintain proper burner adjustment | Use high efficiency burners, air preheater, computer controls |
| 18 | Lube Oil Processing | 0.000 | 0.000 | 0.000 | Maintain proper burner adjustment | Use high efficiency burners, air preheater, computer controls |
| 19 | Engines | 0.008 | 0.000 | 0.001 | Directed I/M program | Install electric motors, gas turbines; for reciprocating compressors modify engines, add catalytic converters, use lean burn engines |
| 20 | Flares | 0.001 | 0.000 | 0.000 | Reduce gas flow to pilots | Use high efficiency burners, replace pilots with igniters |
| | **Total Combustion Emissions** | **0.084** | **0.008** | **0.008** | | |
| | | | | | | |
| | | | | | | |
| | **Total CH4 Emissions, Bcf** | **1.325** | **0.008** | **0.582** | | |